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**OUTLINES**

**OF**

**A COURSE OF LECTURES**



**CHEMISTRY.**

**By T. GARNETT, M. D.** *K*

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A COURSE OF LECTURES



CHEMISTRY

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## PREFACE.

THE following sheets contain, as is expressed by the title, an Outline of the Author's Lectures on Chemistry. They were printed at the repeated request of his auditors, who wished to have a text book which might contain the most striking facts. This text book was intended to be confined to those who attended his lectures, but it having been suggested by some friends, whose judgment and advice he respects, that such a work might be useful in refreshing the memories of others, he has ventured to make it more public. He hopes however, that as this is a mere rude sketch of what is delivered in the lectures, if his readers should not agree with him in some opinions which may appear to be new, they will not censure him, till they have had an opportunity of hearing his defence of those opinions.

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## ERRATA,

Page 60, line 3, after caloric insert a comma,

109, 14, for rochelle salt, read soluble tartar.

## LECTURE I.

### OUTLINES, &c.

## LECTURE I.

**CHEMISTRY** may be justly regarded as one of the most sublime and important of the Sciences, embracing in its object the whole of natural phenomena; there being few changes, comparatively speaking, that are not attended with some effects which come under the consideration of this science.

Some chemists have defined this science negatively, by affirming that every effect which is not merely mechanical, is chemical, and in pursuing this view of the subject, we may say, that chemistry as a science teaches, the methods of estimating and accounting for the changes produced in bodies, by motions of their parts among each other, which



are too minute to affect the senses individually; and as an art, we should say that it consists in the application of bodies to each other, the best calculated to produce those changes.

Macquer says, that chemistry is a science whose object is to investigate the properties of bodies by analysis, and synthesis; and Fourcroy defines it to be a science which gives us a knowledge of the intimate and reciprocal action of all bodies on each other.

It would take up too much time to point out all the advantages which society derives from chemistry, it will only be necessary to point out a few of the most remarkable, with a view of exciting attention, and showing that it is not a science merely calculated to gratify curiosity, and afford entertainment.

Among the arts depending upon chemistry, may be enumerated the making of bricks and tiles, porcelain, and in short, all sorts of earthenware; the making of glass; the arts of extracting, melting, and purifying metals, and uniting them with each other; the formation of vinous liquors by fermentation; the distillation of spirits; the making of vinegar,



vinegar, all depend upon chemistry. The art of cookery is likewise indebted to this science, as well as the arts of tanning, currying, and the manufacture of white leather, and of hats.

To the apothecary an extensive knowledge of this science is absolutely necessary, to understand what alterations the substances which he employs may undergo, and that he may, when necessary, prevent or correct them; and that he may know the combinations and decompositions which take place when different drugs are mixed together.— Numerous mistakes have arisen from a want of knowledge of chemical combination and decomposition in the preparation of medicines.

Chemistry is no less useful to the physician than to the apothecary, as it enables him to prescribe with prudence and success, and to apply with advantage those powerful remedies, which the practitioner, ignorant of chemistry, administers with a timid and uncertain hand. The arts of dying, bleaching, and callico printing, depend upon chemistry, and by means of this science, some of them have been lately wonderfully improved. From what has been said it must be evident that chemistry is the corner stone of the arts; and the science of agriculture is  
much

much more closely connected with chemistry than has generally been imagined. The farmer should know how to mix different kinds of earth and manure, so as to furnish the proper nourishment to plants in due quantity. The prevention and cure of the diseases of vegetables, and the method of destroying the insects which devour them, depend chiefly on a knowledge of chemistry.

The working of mines, and indeed the whole of mineralogy, depends upon chemistry; this science teaches us to extract the different metals from their ores, and to render them subservient to the various purposes of life.

The advantages of chemistry are not however confined to the agriculturist, the natural philosopher, the mineralogist, the physician, or the artist—its phenomena are interesting to all classes of people, and its applications are so numerous, that there are few circumstances which occur in life, in which we do not derive pleasure and advantage from the knowledge of its principles.

Having pointed out in a general way the utility of chemistry, I shall proceed to give a very short historical sketch of this science.

The

## LECTURE I.

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The origin of chemistry is involved in the same obscurity as that of the arts and sciences in general. What Moses says of Tubal Cain, proves that one part of metallurgic chemistry, was understood by that patriarch. Tubal Cain would seem to be the same person mentioned in fabulous history by the name of Vulcan. For many ages after the flood, we have no certain accounts of the state of chemistry: the chemical skill of Moses displayed in his dissolving the golden calf, has generally been adduced as a proof of the flourishing state of chemistry among the Egyptians, in whose learning he is said to be well versed. It seems most probable however, that Moses did not dissolve the calf, but only ground it to powder, and suspended it in water.

But whatever we may think of this circumstance, it is certainly among the more ancient Egyptians that we ought to place the origin of this science. The first of this nation mentioned as a chemist, was Athotis, surnamed Hermes, or Mercurius, who was a king of Thebes; the next king of Egypt who was a chemist, was Siphos, who lived 800 years after Athotis, and about 1900 before Christ; he was surnamed by the Greeks, Hermes, or Mercurius Trismagistus. Democritus of Abdera, who lived about 500 years before Christ, travelled  
into

into Egypt, and obtained a knowledge of their chemistry.

After the lapse of several ages, during which the progress of this science cannot be traced, we again find vestiges of it among the Arabs. In the ninth century, Gebber wrote three works on chemistry, in which some useful facts are to be found; in the tenth century lived Rhafis, physician to the hospital of Bagdat; who first applied chemistry to medicine. In the eleventh century appeared Avicenna, a chemical physician like Rhafis, and a man of great knowledge and abilities, which elevated him to the office of grand vizier; but the debauched life he led soon caused his deposition.

According to writers on alchemy, the art of making gold had been known for a long time; but this notion was carried to its height between the eleventh and sixteenth centuries; when a great part of Europe was filled with searchers for the philosopher's-stone. Among those singular men, were particularly distinguished Albertus Magnus, Roger Bacon, Arnaud de Villeneuve, Raymond Lully, and Basile Valentine.

Although the alchemists were completely foiled in



## LECTURE I.

7

in their researches, yet in the sixteenth century we find a great number of persons fired by the enthusiasm of a gasconading chemist, called Paracelsus, who pretended to have discovered an universal remedy; several of his followers who advanced the science considerably, were by no means cured of the madness which he had communicated; among whom, we may mention Cassius, Libavius, and Van-Helmont.

Chemistry had not hitherto been treated in a philosophical manner, being entirely composed of unconnected facts; but towards the middle of the seventeenth century, Barner, physician to the king of Poland, published a methodical arrangement of the facts then known; his work is valuable, as being the first that places chemistry among the sciences. Bohine afterwards wrote a philosophical treatise on chemistry, which was esteemed as an elementary work; but Becher went much farther than any of them; he collected all the chemical discoveries that had been made, and described, with surprising clearness all the phenomena then known. He was followed by the celebrated Stahl, who undertook to elucidate the doctrines of Becher, and in accounting for many chemical phenomena, he pretended to demonstrate the presence of a principle

ciple of inflammability, which he called phlogiston; his theory was followed till lately by all chemists.

Boerhaave cultivated chemistry, and enriched it with many valuable discoveries, and the celebrated Macquer, contributed the most of any to the advancement of this science.

Stahl, entirely occupied in attempting to demonstrate the presence of phlogiston, overlooked the influence of air, on most of the phenomena which he explained by his favourite principle: but Lavoisier afterwards proved, by a variety of experiments, that a part of the atmosphere combines with bodies during their calcination and burning, and gave rise to a set of chemists who began to doubt the existence of phlogiston, and who attributed to the absorption or disengagement of pure air, all the effects which Stahl thought were owing to the disengagement or absorption of phlogiston. This doctrine possesses many advantages over that of Stahl, as it does not involve the supposition of a substance whose existence cannot be proved; and it accounts for almost all the phenomena in an easy and simple manner, so that it is now almost universally adopted.

## LECTURE II.

**THE** particles of matter are endowed with a reciprocal attractive force, which causes that arrangement we see take place among the different bodies of the universe. This attraction takes place either between particles of the same kind, or between particles of different kinds: the first is called affinity of aggregation, or attraction of cohesion; the latter, attraction of composition, or elective attraction.—The attraction of cohesion has very little effect when bodies are distant, but when they are brought into contact, they unite firmly together. This kind of attraction modifies the apparent, or physical properties of bodies, without influencing in a sensible manner their chemical properties. The attraction of cohesion is stronger the nearer the particles of a body come in contact, and every thing which tends to separate these particles, weakens or opposes this attractive

attractive force; this effect is produced by heat; which entering, or combining with bodies, diminishes the force of attraction. According to the degree with which this force is counteracted by heat, bodies appear in different forms, which may in general be reduced to the following: the hard, or solid aggregate, the soft aggregate, the fluid, and the aeriform aggregate. These different forms are only different degrees of the same attraction, and many bodies are capable of existing in them all.

Besides this attraction existing between particles of the same kind, bodies of different natures exert upon each other an attraction more or less strong; and it is by means of this force, that all chemical changes are effected.

The phenomena of the attraction of combination are regulated by the following laws.

I. It only takes place between the primary, or constituent particles of bodies.

II. The attraction of combination between two or more bodies, is inversely, as the attraction of cohesion.

III. When



## LECTURE II.

11

III. When two or more bodies unite together, in consequence of the attraction of composition, their temperature becomes changed.

IV. The compound which results from the combination of two bodies, has properties perfectly different from those of its constituent parts.

V. Every body has different degrees of attraction, or affinity for the different bodies with which it unites.

The affinity of composition has received different names from its effects, and has been divided into three classes: simple affinity, double affinity, and intermediate affinity.

When two principles united together, are separated by means of a third, this is said to be performed by simple affinity, or single elective attraction.

It often happens however, that when a body is compounded of two others, this combination cannot be destroyed either by a third, or a fourth body, but if both these bodies are mixed with the compound

pound body, it is then decomposed: this is called double affinity, or double elective attraction. The case of intermediate affinity is, when two bodies that have no sensible affinity with each other, are united by a substance which has an attraction for both.

It has been a subject much disputed among chemists, whether the attraction of cohesion and combination, be the same force that Newton denominated gravity. The facts of which we are possessed, will not however enable us to decide the question; but we may conclude, that if chemical affinity, and attraction of gravitation, be one and the same force, the difference which exists in the phenomena produced by them, shews that it is modified by particular circumstances: of this we shall be convinced, if we compare what we know of Newton's attraction of gravitation, with the facts of which we are possessed concerning chemical affinity.

The first takes place between large masses, and is proportioned to the quantity of matter; the latter exists only between the small, and intimate component particles of bodies, and does not take place

at

## LECTURE II.

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at all between bodies of considerable size. The attraction of gravitation takes place at all distances; chemical attraction only when the particles are indefinitely near.

## LECTURE III.

HEAT, in a philosophical sense, denotes the cause of the power which excites particles of extending the vibrations of heat or coldness, though these terms are not always sufficiently accurate, owing to our using a variable standard of comparison for in this instance our sensations are not to be trusted, because the same body may appear hot to one person, and cold to another, or even hot and cold to the same person.

## LECTURE

that the sense of the words must not be thought to accurately defined, and that some fixed standard of comparison be made use of instead of the human body.

Two opinions have long divided the scientific world respecting the nature of heat: the one is, that it consists of a peculiar motion or vibration of the

LECTURE III.

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**HEAT**, in a philosophical sense, denotes the cause of the power which bodies possess of exciting the sensations of heat, or coldness, though these terms are not always sufficiently accurate, owing to our using a variable standard of comparison: for in this instance our sensations are not to be trusted, because the same body may appear hot to one person, and cold to another, or even hot and cold to the same person. Hence it is necessary, in order to avoid error, that the sense of the words made use of should be accurately defined, and that some fixed standard of comparison be made use of instead of the human body.

Two opinions have long divided the scientific world respecting the nature of heat: the one is, that it consists of a peculiar motion, or vibration of  
the



the parts of bodies, the other supposes that heat is a substance, or fluid, whose greater or less quantity produces a higher or lower temperature; the latter opinion seems better supported by facts, but this enquiry will be neither useful, or necessary in the first steps of our investigation, for since effects are always proportioned to their causes, we may speak of the quantities of heat in bodies, without deciding whether they be occasioned by quantities of motion, or quantities of matter.

The fluid, or motion, or whatever it be, which causes the sensation of heat in our bodies has been called *caloric* by the reformers of the chemical nomenclature, which is perhaps the most unexceptionable term that could have been chosen, since it accords with every opinion respecting the cause of heat. Setting aside therefore all enquiries concerning the cause of heat, we shall here confine ourselves to its effects, or phenomena; and shall first consider the most general of them, which heat produces on the simpler kinds of bodies.

The first, and most obvious effect which heat produces on bodies, is expansion; experience has taught us, that at all times when we add heat to a body, we encrease its bulk; this is a very general rule,

rule, the exceptions are few, and will be noticed afterwards: the only difference is in the degree, or quantity of expansion produced by equal additions of heat, in which there are scarcely two bodies that agree together. In general dense bodies expand less than rare ones, but though this may be looked upon as a kind of general rule, there are several exceptions to it.

It is owing to this expansion that the motion of time-pieces is rendered erroneous; but the ingenuity of the artist has discovered a method of obviating this, by employing the greater expansion of one metal, to counteract that of another; this is effected in what is called a gridiron pendulum: upon the same principle has been contrived a particular construction of watches.

Bodies which are brittle, or which want flexibility, crack or break, if suddenly heated, or cooled: this depends upon the expansive power of heat, that stretches the surface to which it is applied, while the other parts not being equally heated, do not expand equally, and are of course torn asunder; hence, vessels which are to stand sudden heat, ought to be very thin. This effect of heat has been applied to several useful purposes in the arts.

There

There are however, some exceptions to this very general effect of heat, and particularly in the case of water; which, when cooled down to the freezing point, instead of contracting on the further application of cold, expands with prodigious force; and this circumstance enables us to explain several curious facts. The reason of this expansion has not been properly explained, but may perhaps depend, as Dr. Black supposes, on some polarity in the attraction, which disposes the particles of the water to unite into a solid, and which at the same time disposes them to run into certain lines and figures, instead of uniting simply together; in consequence of which, little vaguities will be left in the mass, causing it to occupy more room.

Another exception to this general rule, occurs in the case of cast-iron, which swells, or expands considerably in the act of becoming solid; and this is the reason why it takes so fine and sharp an impression from the mould.

There is one curious observation respecting the history of heat, namely, that it never adds in the least to the weight of a body, some experiments which were thought to prove the contrary, have been made, but they are by no means decisive.



We ought to have this effect which heat possesses of expanding bodies in view, when we consider their specific gravities.

Some bodies conduct heat much more quickly than others; metals, for instance, conduct heat with much greater rapidity, than wood, glass, or earthenware; and on this account hot liquors grow cold soonest in metallic vessels.

Heat is greatly retarded in its progress, by rare and spongy substances, such as cork, feathers, or wool; which keep the body warm, by preventing its heat from escaping, and not by any warmth which they themselves possess: in the same manner, snow protects the surface of the earth from the intense cold which would be fatal to vegetation.

If any number of *inanimate* bodies, of different temperatures, be brought together, in a place where there is no positive cause of heat, the heat will flow from the hotter bodies to the colder, till there be an equilibrium. But this is by no means the case with respect to *animated* matter; for, whatever be the degree of heat peculiar to individual animals, they preserve it nearly unchanged in every temperature;



rature ; which shews, that they neither receive their heat from the bodies surrounding them, nor suffer from external circumstances, any material alterations in their heat ; which leaves us no room to doubt, that they are furnished with a power of generating, supporting, and regulating their own temperature. We shall afterwards be enabled to see on what this power depends.

## LECTURE

## LECTURE IV.

BEFORE we proceed farther respecting heat, it will be necessary to say something concerning thermometers ; which are very useful instruments, and which have greatly enabled us to enlarge, and correct our ideas respecting heat. The invention of the thermometer is involved in obscurity, but Sanctorio seems to have the best claim to it : he appears to have been the first who noticed the expansive power of heat ; and observing it in the case of air, thought of employing it to ascertain the different degrees of heat. Sanctorio's aerial thermometer, afterwards improved by Mr. Boyle, was remarkably sensible ; but, as it was liable to be affected by variations in the weight of the atmosphere, as well as of its heat, it could not be depended on. The object therefore, was to construct thermometers with some other fluid than air, which would not need to have  
any

any communication with the atmosphere. Spirit of wine, tinged of a red colour, was first used for this purpose, and is, even still preferred by some; though mercury is now generally used, and is undoubtedly the most proper fluid for the purpose. The only difficulty which remained, was to graduate them in such a manner, that all thermometers might exactly correspond with each other, which at first sight was by no means obvious. The first attempts were very rude, and imperfect; neither was the method proposed by Mr. Boyle much to be trusted to; as, it depended on the measurement of the capacity of the ball, and bore of the tube, by mechanical means, which could not accurately be done.

It was afterwards discovered, that some bodies always changed their form at the same temperature, or, that when they pass from a solid, to a fluid state, and the contrary, they always reduce the fluid in the thermometer to the same degree of expansion, so that, by obtaining two, or more, such fixed points, thermometers may be graduated so as to correspond exactly with each other. It is likewise found, that the dilatations and contractions of mercurial thermometers, are very nearly proportionate to the quantities of heat communicated to, or subtracted from them, which is a very satisfactory

tory discovery, and which was ascertained by producing three different temperatures independent of a thermometer, and which were intended to serve as a check upon it, and shew whether it pointed to the different quantities of caloric that really obtained.

These thermometers, are however, liable to some imperfections : the first is, that they are incapable of measuring great degrees of heat ; because the fluid which they contain, when heated above a certain degree, is converted into an elastic vapour that would burst the vessel.

Mr. Wedgewood has however, contrived an ingenious method of measuring any degrees of heat, however intense, by means of small pieces of clay, which contrary to the general rule before mentioned, contract in proportion to the degree of heat to which they are exposed.

Another inconvenience to which thermometers are subject, is, that we cannot by means of them ascertain the degree of heat or cold that happens in our absence. This is obviated in a great measure by Mr. Sixe's ingenious thermometer, the indices of which point to the greatest degrees of heat or cold



cold that take place during any length of time that the observer may be absent. This thermometer, though very ingeniously contrived, is too complicated for common use, and not portable; but a much more simple one on the same principle might be easily contrived.

There are a variety of scales adapted to thermometers, different ones being used in different countries; which is a circumstance attended with no small inconvenience in comparing observations that have been made with various thermometers; and it is much to be wished that a general or standard scale were adopted. The scale used in this country is that of Farenheit, which is particularly described in the lecture.

LECTURE V.

**HEAT** enters with equal celerity into different kinds of bodies, but they are not all equally easily saturated with it, or in other words, have unequal capacities for receiving it.

The celerity with which heat passes from hotter bodies to colder, is, *ceteris paribus*, in proportion to their difference of temperature; and also to the extent of contact. Hence the excessive slowness with which heat is communicated from one part to another in bodies that are more spongy and light, while it readily passes through those that are dense and heavy. It is on this account that light spongy substances, such as feathers and wool, keep us warm in cold weather, as was observed before. From this likewise we see the reason why snow, when it lies pretty thick upon the surface of the earth, prevents

vents its being cooled much below the freezing point, and thus preserves the roots of vegetables from those intense colds which would otherwise destroy them.

We daily see bodies rendered fluid by means of heat, and have reason to be persuaded, that whenever we meet with fluidity, it is always an effect, or consequence of heat: even those bodies which appear generally in a fluid state, and which state might seem to be natural to them, derive their fluidity from the quantity of heat which they contain. Heat may therefore be considered as the cause of fluidity in all bodies whatever; but as there is a great diversity with regard to the *quantity* of heat necessary to produce this effect, it would appear that there are some other circumstances that affect their disposition to fluidity.

We may however consider all fluid bodies, as solids melted by heat, but whose congealing point is lower than the natural temperature of the atmosphere.

Some philosophers have found great difficulty in admitting this general proposition; and have thought water an exception. They have supposed  
fluidity

fluidity to be an essential quality of water, depending upon the spherical figure of its particles, and that its freezing depends upon the introduction of extraneous bodies; of this opinion was professor Muschenbrook, who has given a number of arguments in favour of this supposition, none of which are however satisfactory.

It has been generally supposed, that bodies in passing from a solid to a fluid state, receive no more heat than what is indicated by the thermometer, and that the extrication of this *sensible* heat, is sufficient to reduce them again to a state of solidity; but the excessive slowness with which ice melts, when surrounded by an atmosphere, many degrees above frost, and which must therefore be constantly communicating heat to it; as well as some curious phenomena attending the freezing of water, shew that the heat must be received in some different manner.

According to Dr. Black, the fluidity of bodies does not depend so immediately upon the *sensible* heat which they contain, as upon a certain quantity of *latent* heat, which is combined with, or lies concealed in the mass, so as not to appear to the sense, or affect the thermometer; but which is ready to  
break



break out, and assume the ordinary form of sensible moving heat. A certain quantity of sensible heat he supposes necessary to fluidity, but the immediate and indispensable cause is, the entrance of a certain quantity of heat which becomes chemically combined with the body, and which continues in this condition, without suffering any increase or diminution, while the body continues fluid, but when it passes to the solid state, this heat becomes disengaged, and enters into the surrounding bodies, augmenting their temperature. A fluid may hence be considered as a body combined with caloric.—The solid form is therefore the natural state of water; in a fluid state, it is a combination of ice and caloric. The quantity of heat which enters ice, and which gives it fluidity without augmenting its temperature, may be calculated.

Dr. Black, from some experiments which he made, supposes the heat necessary to melt ice, without augmenting its temperature, to be  $147^{\circ}$ ; but some other philosophers, who have considered the subject more accurately, have found that ice cannot become water, unless it receive  $130^{\circ}$  of heat. This ingenious theory enables us to explain many phenomena relating to heat and cold, which cannot otherwise

otherwise be accounted for; such as the extreme degrees of cold produced by mixing different salts with snow, or with the mineral acids; the excessive flowiness with which ice melts; the reason why melted metals when in large quantity are so long in becoming solid, &c.

LECTURE

## LECTURE VI.

TO form a more exact idea of the conversion of fluids into elastic vappurs, suppose a single drop of water put into a copper or bräs globe, capable of holding some gallons, and the globe perfectly exhausted of its air ; if we apply heat to it, and had an opportunity of seeing what happens within, we should find that the water would suddenly disappear, and assume the form of a transparent vapour, which would immediately fill the whole cavity of the globe in an equable manner ; and if the heat be further increased, the elasticity, expansion, or force of the vapour, will be increased to such a degree as to burst the globe.

In general, the conversion of any particular body into vapour, depends upon its being heated above a certain degree ; and this vapour immediately collapses,

lapses, as soon as the heat is diminished below that degree.

This degree is much higher than that required to convert them into a state of fluidity; and every body has a particular degree of heat at which it assumes the form of vapour, in the same manner as each requires a peculiar degree of heat to reduce it to fluidity. It is not found however, that those bodies which soonest assume the form of a fluid, require the lowest degrees of heat to convert them into vapour; for though this may be regarded as a kind of general rule, there are many exceptions to it.

Those substances which are easily converted into vapour, are called *volatile*, and those which require a very strong heat, are called *fixed*.

Though the degree of heat required to convert a particular body into vapour, is in general nearly the same, yet it is not so steady as the melting point; for we find, that when pressure is applied to the surfaces of bodies, it retards very much their conversion into vapour, and enables them to bear a much greater heat before they boil. In Papin's  
Digester,



Digester, water will bear to be heated nearly red hot, without being converted into vapour.

Under the pressure of the atmosphere, all bodies are found to receive more heat than they otherwise would do, and when we consider that this pressure is fifteen pounds upon every square inch, we shall not be surprized that it should enable water to bear  $120^{\circ}$ . more heat before it boils, than is required to make it boil in vacuo.

When heat is applied to the bottom of a vessel containing water, as soon as it becomes heated to a certain degree, it is affected with that agitation which we call boiling, which is occasioned by the small bubbles of vapour formed at the bottom of the vessel, where the heat enters most plentifully; this vapour being much lighter than the water, rises rapidly through it, and is thrown up to the surface with violence.

The violence of this agitation is proportioned to the celerity with which heat is thrown in, and however long or violently the fluid is made to boil, it will not become the least hotter.

The operation of heat in producing vapour, is  
similar

limilar to its operation in producing fluidity. The conversion of a body into vapour does not depend so immediately upon the quantity of *sensible* heat, as upon a quantity of heat which becomes absorbed, or latent, in such a manner as not to be evident to the sense of touch, or to the thermometer; but which is ready to break out, when the body is condensed into the form of an incompressible fluid.

This opinion is confirmed by several observations, particularly by the great quantity of heat received by water during its ebullition, which does not appear in the vapour, but which is given out by the vapour when it is condensed in the process of distillation.

There are other examples which show the change of sensible into latent heat, during the conversion of bodies from their ordinary state into that of vapour. If the bulb of a thermometer be moistened with ether, the mercury will sink in the tube on the evaporation of the ether; and if the pressure of the air be removed from the surface of the ether, it will evaporate so quickly as to produce a very great degree of cold, if a tube be filled with water, and immersed in the ether, the water will soon be frozen by the evaporation of the ether.

A very

A very great degree of cold may be produced by mixing neutral salts with the mineral acids in various proportions. The cold produced in this way is so intense, that mercury may be frozen at any time when the temperature of the air does not exceed  $85^{\circ}$  of Fahrenheit's scale.

THOUGH it is evident from what has been said that the different forms under which bodies appear depend upon their latent heat, or caloric which is combined with them, yet their permanency, or continuance in any form, depends on their quantity of sensible heat. Water is solid in all degrees below  $32^{\circ}$  of Fahrenheit's scale, it then is disposed to combine with caloric, and become a fluid, it retains its fluidity under the ordinary pressure of the atmosphere, till its sensible heat is augmented to  $212^{\circ}$ , it is then disposed to absorb a much larger portion of caloric, and is converted into a gas, or elastic vapour, in which state it would always continue, if the heat of the atmosphere was above  $212^{\circ}$ .

D. LECTURE

## LECTURE VII.

THOUGH it is evident from what has been said, that the different forms under which bodies appear, depend upon their latent heat, or caloric which is combined with them; yet their permanency, or continuance in any form, depends on their quantity of sensible heat. Water is solid in all degrees below  $32^{\circ}$ . of Fahrenheit's scale, it then is disposed to combine with caloric, and become a fluid; it retains its fluidity under the ordinary pressure of the atmosphere, till its sensible heat is augmented to  $212^{\circ}$ . It is then disposed to absorb a much larger portion of caloric, and is converted into a gas, or elastic vapour, in which state it would always continue, if the heat of the atmosphere was above  $212^{\circ}$ .

Ether boils, or is converted into an elastic fluid, when



when heated up to  $106^{\circ}$ , and if we could keep it in this degree of heat, it would always be in the form of an elastic fluid.

All gases, or elastic fluids, therefore, depend upon the combination of particular substances with caloric; and those which we call permanently elastic, are only so, because we cannot so far reduce their temperature, as to dispose them to part with their latent heat, otherwise they would undoubtedly become fluid or solid.

Though the vaporific point of most bodies is higher than what is necessary for their fluidity, this is not the case with regard to all; for there are some solid bodies which begin to be converted into vapour by a smaller degree of heat than is necessary to render them fluid.

From observations on the manner in which vapour is produced from different bodies, we can understand several chetnical operations, such as evaporation, distillation, and sublimation. With regard to evaporation, we may lay down the following general consequences.

If any thermometer be plunged into an evaporable

porable fluid, and immediately taken out again, the mercury will descend several degrees while the bulb is drying; but as soon as the fluid is evaporated, it will begin to rise, and continue to do so, till it has acquired the temperature of the surrounding air.

2. The cold produced is greater in proportion as the fluid is more evaporable.

3. If the evaporation be accelerated by any means, excepting heat, the cold will be proportionally augmented.

Though the property of producing cold by evaporation has been but lately observed by chemists, yet it has been long employed by those who knew nothing of the operation. In hot climates they employ it to cool their liquors, and even to keep the temperature of the body cool.

The making of ice in warm climates, where it is one of the luxuries of life, depends on the same principle.

On this principle also we can see the reason why the air over a wood or forest is cooled by evaporation from trees and shrubs, and hence the shade formed

formed by vegetable bodies, is more effectual in cooling us, than the shade of rocks and buildings.

When the human body is heated, the vapour passes off through the skin by perspiration. If this perspiration be lessened, what should evaporate, heats the body to an improper degree. Hence the utility of remedies which promote perspiration, and the use of ether when applied to the temples and different parts of the surface of the body.

Spontaneous evaporation is the production of a vapour from bodies, distinct from that elastic vapour produced by increasing their heat above their boiling point; it is produced slowly and imperceptibly, without the least agitation; it is evident therefore that it must proceed from the surface, and is accordingly found to be more copious as the surface is increased; but if the air, loaded with this vapour, be allowed to stagnate upon the surfaces of the bodies from which it has been produced, the fluid will not evaporate by any means so fast as it did before. Hence in calm weather, water evaporates more slowly than when the air is agitated by winds.

The production of this vapour, though it does not appear to possess any elasticity, depends however upon



upon heat; and when a considerable quantity of it has been produced, and the heat suddenly diminished, the vapour will be condensed, and form a mist or dew; or if the cold be great, a hoar frost.

It is this evaporation which is going on from the surface of the sea, lakes, rivers, and the earth, which produces the vapour, that at a certain height is condensed by cold into mist, and composes clouds, which are suspended at different heights in the atmosphere; which are carried about by the air, and are liable to become electric, and in consequence of this produce the phenomena of thunder and lightning: these clouds being farther condensed, fall in drops of rain, which form springs and lakes, from whence arise rivers and seas.

On account of the importance of spontaneous evaporation in many of the grandest operations in nature, various attempts have been made to explain its cause, particularly by Derham, De Saguliers, and others; none of which are however satisfactory. One of the most ingenious theories is that given by Dr. Hamilton. He supposes that spontaneous evaporation, which takes place in low degrees of heat, depends on the attraction between the air and the water; and that the air dissolves wa-

ter



ter in the same manner that water dissolves salts, and many chemical fluids dissolve metals. This theory is supported by a number of circumstances, in which it seems to agree remarkably with the dissolution or combination of salts or metals with fluids, and to account very well for the phenomena; but there is an insurmountable objection to it; viz. that this evaporation goes on in vacuo, even more rapidly than in the open air, which it could not do if it depended on the solution of the water in the air.

A variety of circumstances, and particularly the cold which is produced by spontaneous evaporation, shew, that this, as well as the formation of other vapours, depends upon the absorption of heat into a latent state.

When heat is accumulated in bodies to such a degree that they emit light, they are said to be *ignited*. There seems a curious connexion between light and heat; when a body is heated intensely, it always becomes luminous, and the light of the sun, when concentrated, is capable of producing a most intense heat in opaque bodies. But though there would seem this strict connexion between them, it seems probable that the light of the sun does not contain any heat. The rays of the sun,  
in

in their most concentrated state, produce no heat when they fall upon transparent bodies. If the rays of the sun communicated heat to the earth, this planet would be gradually heated to an intense degree, as there does not seem any way in which the heat can be conveyed from it to other bodies. It appears much more consonant to the phenomena, to suppose that the rays of the sun, falling upon bodies, become attracted by, and combined with them, and thus diminish their capacity for heat, so that their combined caloric will be disengaged and become sensible. There exists probably therefore, always the same quantity of caloric in the earth, and the atmosphere which surrounds it; and this caloric is either in a combined or free state. Different processes disengage the combined caloric, which then becomes free.

When a piece of iron is made red hot, the light is perhaps given out by the oxygen, on its union with the ignited body, so that the red appearance of iron is most probably a species of combustion. The same body not only always requires the same degree of heat before it becomes red, but all kinds of matter capable of bearing a red heat, become red about the same time.

As

As light is an agent of some consequence in chemistry, it may not be improper to consider some of its properties here, though the most remarkable belong to the science of optics. I shall only therefore give a very short view of its physical properties.

Light seems to consist of particles of matter, extremely minute, which are emitted from the sun, and other luminous bodies, in right lines; its velocity is so great, that it moves from the sun to the earth in little more than eight minutes. The elasticity of the rays of light is so great, that the angle of incidence is equal to the angle of reflexion. Light has gravity, for it may be attracted and inflected by different substances.

The light of the sun, which is white, is composed of rays of seven different colours, which may be separated by refraction in the following order.—Red, orange, yellow, green, blue, indigo, violet.

Light is now no longer considered as a mere physical agent; the chemist is sensible of its influence in a variety of operations. Vegetation cannot go on in perfection without light, for plants deprived of it are perfectly white and weak; and when the light is permitted to enter into a dark place where vegetables



vegetables are growing, they all tend towards it, as if sensible of the necessity of this fluid to their existence.

Deprived of the benign influence of light, the colour of all vegetables would be a deadly white; they are even deprived of their beautiful tints which they have already acquired, when they are shut up in darkness. Vegetables not only owe their colour to light, but also their odour, flavour, and combustibility. We see the influence of this element likewise exerted on other bodies. Worms, and insects which live in darkness, are white; so are the birds, and butterfly tribe, which fly about only in the night. Several experiments made by Scheele and Berthollet, shew that the absence or presence of light, varies and modifies in an astonishing manner, the results of chemical operations.

Instances have been already given in which cold is produced by mixture; many likewise occur in which heat is produced. When cold was produced, it was shown that heat was absorbed, and became latent in the mixture; but here, that heat which was before latent, becomes sensible.



## LECTURE VIII.

IN this lecture the laws of chemical affinity, or affinity of composition, illustrated in the second lecture, are recapitulated, and afterwards the effects which take place when bodies are mixed together, are considered.

In some instances, when bodies are mixed together, they cannot by any means be made to combine, or unite: as is the case with mercury, sand, or oil, when mixed with water. However violently these bodies are agitated, they will soon separate. In other instances however, bodies on being mixed together, readily unite, and form a homogeneous compound, in which we cannot discover the smallest appearance of any diversity of constituent parts. In some cases this intimate union is effected slowly, and in a gentle manner, and is  
not

not accompanied by any phenomena which attract the attention; but there are other bodies whose union is attended with a violent agitation, and the production of heat. In some instances the commotion is very violent, and the mixture breaks out into a cloud of smoke, or even into flame. These circumstances are particularly applicable to the union of fluids with each other; but there are many instances in which solids, even very hard bodies, upon being thrown into certain fluids, are torn asunder. In all cases where the solid is thus divided, and united to a fluid, it is called by chemists a *solution*, and the fluid is called the *solvent*. It is necessary to distinguish between solution and diffusion. When a piece of clay is mixed with water, it will become diffused in it, but the mixture will be turbid, and in time the clay will separate from the water and fall to the bottom, as there is no chemical combination between them. In all cases of real solution, the compound becomes transparent, so that transparency may be regarded as a general criterion of solution.

When a liquid has dissolved a certain quantity of a solid, if more be added, it will not be dissolved; the liquid is then said to be saturated with the solid.

A curious

A curious circumstance takes place in some instances of solution, which is not easily accounted for. When a fluid has dissolved as much of a certain solid as it can, it will still dissolve the particles of another body; and when it is saturated with this, it will dissolve a third, and so on. This is however only true with regard to some particular solvents, for in others, when a third substance is added, it cannot be dissolved, unless the body previously dissolved should be precipitated.

When substances are combined which differ in volatility, they may be separated by heat, which converts the more volatile body into vapour, while the less volatile remains. Two bodies may likewise be separated from each other by the addition of a third body; of this a number of instances may be given.

There are few substances found in a natural state, whose constituent parts cannot be separated from each other, by some of the methods used in chemistry. One of the principal methods consists in altering the temperature of bodies. The parts of some bodies are separated from each other by exposing the compound body to a great degree of cold, when some of its parts will congeal, while the others



others remain fluid; but the purposes of chemistry are in general, much better answered by raising, than by lowering the temperature of bodies. The most usual way of heating bodies, is to place them in communication with others which are in a state of combustion. The vessels and furnaces made use of for these purposes, are various, according to their several applications.

When substances of considerable fixity are to be exposed to heat, or when the volatile parts of bodies are proposed to be dissipated into the air, open vessels are used.

The common culinary utensils of copper or iron, answer these intentions, when the matter to be operated on, will not corrode them. Glass vessels are the most cleanly, and may be used for a great variety of chemical purposes. They have the advantage of resisting the most corroding matters, and their transparency affords the valuable convenience of seeing the changes which happen within them.

In most operations where the volatile parts of bodies are proposed to be separated and preserved, it is necessary to use close vessels. The apparatus generally



generally used for this purpose, is the common still. But there are many matters required to be distilled, that are not sufficiently volatile to pass into the receiver in this way. In such cases the refrigeratory is omitted, and a retort is used, with a receiver luted to its neck.

The construction of furnaces is as various as the purposes they are designed to serve. A lamp supported at different distances below any chemical vessel, or burning with a variable number of wicks, is very useful when moderate degrees of heat are intended to be applied. For higher degrees, furnaces of different constructions must be used. Chemical vessels may be plunged to a greater or less depth in a pot placed over the furnace, containing sand, water, or other matter capable of sustaining heat. These substances interposed between the vessel and the fire, compose what is called by chemists a bath, and are very useful in imparting an uniform heat, not subject to the sudden vicissitudes experienced by vessels exposed to a naked fire. Without this contrivance, glass vessels would often fly and crack. Glass or earthen vessels intended to sustain a greater heat than can be given by means of a bath, must be coated. A valuable method is adopted

adopted by Mr. Will, to secure and repair his retorts used in the distillation of phosphorus.

The philosophical chemist may in general perform his operations without the absolute necessity of using furnaces constructed on purpose, or preparing any large apparatus of vessels. A tobacco-pipe is a very good crucible, with which many experiments may be made in a common fire, with the assistance of a pair of bellows. Common chafing dishes, or the larger sort of black lead crucibles, may be applied to purposes of extensive utility.— A Florence flask will form as good a retort as can be used, and a phial with a wide neck, luted to the flask, will serve as a receiver.

The blow-pipe is an instrument of great use in the chemical examination of bodies, particularly minerals. The advantages attending experiments with this instrument, are many. They may be made in a very short time, in any place, by an apparatus that admits of being carried in the pocket; the quantity required of any material is so small, that they are performed at very little expense, and the whole process is visible from the beginning to the end. If instead of air from the lungs, or a pair of bellows, oxygen gas be used with the blow-pipe, a greater

a greater degree of heat may be obtained, than by any other method yet discovered. In making experiments on gases, or aeriform fluids, it is often necessary to pour them out of one vessel into another, and to mix them together; this may in general be done under water, in a cistern proper for the purpose, such as Dr. Priestley used in his experiments on airs. But many kinds of air combine with water, and therefore require to be treated in an apparatus in which mercury is made use of. This fluid being very ponderous, and of considerable price, motives both of convenience and economy require that the apparatus should be made much smaller than when water is used.

E

LECTURE



LECTURE IX.

**THE** earth is surrounded or encompassed by a thin transparent, invisible fluid, called the atmosphere, which reaches to a considerable height above its surface. This fluid, though invisible to us, is a real substance, as appears by its excluding other substances from the space which it occupies. It is likewise heavy, and presses with considerable force, and as it is a fluid, it presses like other fluids equally in all directions.

The weight of the air is the cause of the suspension of mercury in the barometer, and of the action of pumps. The weight of atmospheric air is to that of water nearly as 1 to 900, and the atmosphere near the earth's surface, presses with a weight of fifteen pounds upon every square inch.

As



As air is an elastic fluid, it is capable of occupying more or less space according to the pressure it sustains, and its spring or resistance is always proportioned to that pressure.

These properties are called the mechanical or physical properties of the air; but whether it be a simple homogeneous fluid, or consists of a mixture of gases, belongs to the province of chemistry to ascertain. Chemistry affords two general methods of determining the constituent principles of bodies, analysis and synthesis; both of which can be used in the most satisfactory manner in our investigations of the nature of atmospheric air. From some ingenious experiments, M. Lavoisier has proved, that the air of the atmosphere is not a simple homogeneous fluid, but consists of two elastic fluids, possessed of very different properties; one of which supports combustion, and animal life much better than common air; and the other is incapable of supporting either for an instant. These two fluids exist in the atmosphere in the proportion of twenty-seven of the former, to seventy-three of the latter.

The atmosphere contains some other gases, or substances capable of being dissolved or suspended in

in it, but in small quantity, and these are the two principal substances of which it is composed.

In the new Nomenclature, the terms are taken chiefly from the Greek language, in such a manner as to make their etymology convey some idea of what is meant to be represented, and these are made short, and contrived in such a manner as to be easily changeable into adjectives and verbs. Following these principles, the term gas has been retained, and the numerous class of aeriform elastic fluids have been arranged under that name. Gas therefore in the new Nomenclature, becomes a generic term, expressing the fullest degree of saturation of a body with caloric. To distinguish each species of gas, a second term is employed for the name of the base, which saturated with caloric, forms each particular gas.

The pure part of the atmosphere is called *oxygen gas*, from the most general property which its base possesses of forming acids, by combining with different substances. The chemical properties of the noxious portion of the atmosphere being but little known, the name of its base is taken from its known quality of killing animals, and is therefore called

*azote.*

*azote*. Hence the name of the noxious part of the atmospheric air is *azotic gas*.

This term is certainly not the most proper that might have been chosen, because it does not point out any exclusive characteristic of the substance, and it is surprizing that the authors of the new Nomenclature did not call it *nitrogen*, which would have been unexceptionable, and perfectly agreeable to the principles on which the new Nomenclature is founded.

From the numerous improvements and discoveries lately made, chemistry was become a science of the utmost importance; and many of the ancient terms being very barbarous, as well as conveying false ideas, a new Nomenclature became highly necessary.

The method adopted for fixing the names of compound substances, seems simple and natural; as will appear from the following instances.

The authors of the new Nomenclature begin with comprehending under a general denomination, the combination of any acid with its different bases; and in order to simplify the subject, and assist the memory,



memory, they have given the same termination to all the words which denote the combinations of acids, such as *sulphat*, *nitrat*, and *muriat*, to denote the combination of the sulphuric, nitric, and muriatic acids, with different substances. The species of combination is known by adding to this generic name, that of the body which is combined with the acid.

Some of the bodies which are convertible into acids by union with oxygen, are capable of different degrees of saturation with that principle, by which their properties become altered. When a body is completely saturated with oxygen, the termination is *ic*, as the *sulphuric acid*, but when it is combined with it in a smaller degree, the termination is *ous*, as the *sulphurous acid*.

## LECTURE



( 55 )

## LECTURE X.

**THE** discovery of *oxygen gas* is perhaps the most important that ever was made in Chemistry. This elastic fluid was discovered by Dr. Priestly in the year 1774. Since that time it has been extracted from a variety of substances.

When a metal is exposed to the air, and at the same time to heat, it loses its metallic lustre, and acquires the form and properties of an earthy substance. If this change be produced in a given quantity of atmospheric air, the calcination can only be carried on to a certain degree; and on examining the air which remains, we shall find that it has lost the whole of its oxygen, and that nothing remains but the azotic gas. If we examine the metallic calx, we shall invariably find it heavier than the metal from which it was produced, and  
this

this augmentation of weight will be exactly proportioned to the loss of weight sustained by the air.— Hence it appears that the oxygen of the air becomes united to the metal during calcination. On exposing the calx, or oxyd of mercury to a considerable heat, the metal will be revived, and a quantity of oxygen gas may be procured from it. If the calcination of a metal be performed in pure oxygen gas, it will go on much more rapidly than in atmospheric air, and if the quantity of metal be sufficient, all the air will be absorbed,

Since oxygen gas contains a large quantity of caloric, and light, in a latent or combined state, we should expect that when the oxygen becomes fixed in a metal; this heat and light would become sensible. But the quantity of either disengaged in any minute portion of time, is so small as to be insensible, and the heat becomes confounded with that of the furnace. This disengagement of caloric and light however is very sensible when bodies are calcined in pure oxygen gas. If a piece of iron be heated and plunged into this gas, it burns with great brilliancy, and becomes oxydated.

But though pure oxygen gas may be procured from oxids of mercury, merely by the action of heat,

yet

yet the oxyds of other metals cannot be reduced without the addition of some substance to which the oxygen has a greater affinity than to the metal. If charcoal be mixed with the metallic oxid, it will unite with the oxygen and form carbonic acid, which will fly off in the form of gas, while the metal will be reduced. Hence it is evident that the calcination of metals is nothing but their union with oxygen, and is therefore properly called their oxydation. This is very different from the theory delivered by Stahl, and supported by his followers.— They imagined metals to be composed of a certain earth which they called their calx, and phlogiston; during the calcination they supposed the phlogiston to be driven off, or dissipated, and imagined that it could not be restored to them, or that they could not be revived, unless heated in contact with some substance which they supposed to contain phlogiston. This theory was however attended with insurmountable difficulties, and involved its advocates in continual absurdities. The mere reduction of mercurial oxyds by heat alone, is of itself sufficient to overturn it.

The principal phenomena which take place when combustible bodies are heated in contact with air, are heat, motion, flame, and an entire change of the



the nature of the body burned. Some bodies burn with very great rapidity, others more slowly, and others without any apparent motion or flame. If combustion be performed in such a manner that all the products formed by it can be preserved and collected, these products are always heavier than the body which has been burned. It has been long known that combustion could not take place excepting atmospheric air was present, and it has been explained in various ways.

According to Lavoisier's theory it appears, that combustion differs from the oxydation of metals, chiefly in its being more rapid; and in the products being many of them volatile instead of fixed. This analogy will lead to an easy explanation of combustion. If we consider a familiar instance, the combustion of coal in a common fire, we shall find that it will be first necessary to apply heat, because the combustible body is not disposed to combine with oxygen, till the cohesion of its particles are diminished by caloric. When this is done to a certain degree, the coal combines rapidly with oxygen, and during the combination, the oxygen gives out the heat and light which preserved it in the form of gas. Though a great weight of coal is consumed, and only a few ashes left behind, yet if all the volatile

volatile products be collected, we shall always find them heavier than the coal was before combustion.

Oxygen gas contains a much greater quantity of combined caloric than any other substance with which we are acquainted; but carbonic acid gas has a much less capacity for heat than oxygen gas; when therefore oxygen gas combines with charcoal, part of its heat remains latent, and preserves the carbonic acid which is formed in a gaseous state, while a considerable portion assumes the form of sensible heat.

From this theory of combustion, we are enabled to explain a variety of phenomena; for instance, why the direct light of the sun puts out a fire; why a fire burns brighter in frosty weather, &c. When oxygen in the form of gas unites with a combustible body likewise in the form of gas, the combination is very rapid; and as the compound which is formed generally occupies much less space than the two substances did, a vacuum will be formed; and the surrounding air rushing in from all sides to replenish the vacuum, causes a very loud report.

## LECTURE

## LECTURE XI

FROM what has been said, it is evident that oxygen has a greater affinity for metals heated to a certain degree, than for caloric in consequence of which all metallic bodies, except gold, silver, and platinum, have the property of decomposing oxygen gas, by attracting its base from the caloric with which it was combined. The affinity of combustible bodies for oxygen is greater than that of metals for the same substance, they therefore unite with it rapidly, and in combining with them, the oxygen gives out a great part of the light and caloric which supported it in the state of gas. Though most combustible bodies require to be heated before they combine with oxygen, yet some of them have so strong an attraction for it, that they will unite with it in the ordinary temperature of the atmosphere.

The



The following laws may be deduced from what has been said concerning combustion.

1. Combustion cannot take place without the presence of oxygen.

2. In every instance of combustion there is an absorption of oxygen.

3. In the products of combustion there is always an augmentation of weight, equal to the quantity of oxygen absorbed.

4. In every instance of combustion, light and heat are disengaged.

The phenomena of combustion may be distinguished into three states, ignition, inflammation, and detonation. The first takes place when the combustible body is not in an aeriform state, nor capable of assuming that state; the second when the combustible body in the form of vapour, or gas, comes in contact with oxygen gas. The third is a sudden inflammation, which occasions a noise by the instantaneous formation of a vacuum. In the greatest number of instances in which detonation takes place, this phenomenon is produced by the combustion of hydrogen gas with oxygen.

When we consider the phenomena of respiration, we shall find them very analogous to those of combustion. A candle will not burn, nor an animal live, in an exhausted receiver. When a candle is confined in a given quantity of atmospheric air, it will burn only for a certain time; and on examining the air in which it has burned, the oxygen gas is found to be all extracted, nothing remaining but azotic gas, and a quantity of carbonic acid gas; in the same manner, if an animal be confined in a given quantity of atmospheric air, it will live only a short time, and the air will have lost its oxygen, nothing remaining but azotic and carbonic acid gas.

A candle will burn, and an animal live much longer in pure oxygen gas, than in the same quantity of atmospheric air.

From considering the phenomena attendant on respiration, we may lay down the following general propositions.

1. An animal cannot live unless it be supplied with oxygen.
2. All animals do not require air of the same purity;

purity; birds require air of greater purity than man, or animals which live upon the surface of the earth; and those animals which live principally under ground, or which pass the winter in a torpid state, require an air much less pure than other animals.

3. The mode of respiration is different in different animals.

The air which has served for respiration is found to contain a mixture of azotic and carbonic acid gas, with a small quantity of oxygen gas, and a considerable quantity of water is thrown off from the lungs in respiration.

From a variety of facts it appears, that oxygen gas is decomposed in the lungs during respiration; a part of the oxygen unites with the iron contained in the blood, and converts it into an oxyd; another and greater portion unites with the carbon brought by the venous blood to the lungs, and forms carbonic acid gas, while another portion of the oxygen unites with the hydrogen brought in the same manner, and forms water.

A portion of this oxygen which unites with the  
iron



iron and hydrogen, becomes fixed on these substances, and gives out the heat which supported it in a gaseous state, while the remainder forming, carbonic acid gas, which has a less capacity for heat than oxygen gas, gives out a part of its caloric. Thus respiration is the cause of a continual extrication of heat in the lungs, which being conveyed by the blood to all parts of the body, is a constant source of heat to the animal. We may therefore consider respiration as an operation in which oxygen gas is continually passing from the gaseous to the concrete state; it will therefore give out at every instant, the heat which it held in combination.

These facts enable us to explain the reason why an animal preserves nearly the same temperature notwithstanding the various changes which occur in the temperature of the surrounding atmosphere, which enables the human body to bear vicissitudes that would otherwise destroy it. They likewise enable us to account for the difference of heat in different classes of animals; their heat being always proportioned to the quantity of oxygen gas which they decompose.

Combustion and respiration are continually diminishing the quantity of oxygen contained in the atmosphere;

atmosphere; if therefore the wise author of nature had not provided for its continual reproduction, the air must soon become too impure to support life; but vegetables absorb water and carbonic acid gas, which substances they decompose, and appropriating the hydrogen of the former, and the carbon of the latter to their nourishment, exhale the oxygen gas in a very pure state:—thus animals and vegetables work the one for the other, and by this admirable reciprocity, the atmosphere is always kept sufficiently pure, and the equilibrium of its component parts constantly maintained.

**F LECTURE**

## LECTURE XII.

IN the last lecture it was hinted, that part of the oxygen received into the lungs, combined with the *iron* which exists in the blood; and it will not perhaps be improper to examine this idea more accurately.

That iron exists in the blood, may be proved from a variety of circumstances; and particularly by the chemical analysis of that fluid. This iron may be conveyed into the blood, by the articles of food, most of which contain some portion of this metal, though small; but it is more probable that the greatest part of the iron found in this fluid, is the product of animal organization; indeed several facts may be produced, that seem to show, that the greatest part of the iron which exists in nature, has been formed by vegetable and animal processes.

It



It appears likewise that the red colour of the blood depends upon the oxydation of this iron, which that fluid contains in a state of extreme division. If the coagulable lymph and serum be carefully freed from the red particles by washing, the strictest analysis will not discover in either of them a particle of iron, while the red particles thus separated, consist almost entirely of this metal.

That the red colour of the blood depends upon the combination of its ferruginous particles with oxygen, appears from the beautiful experiments of Menghini, Thouvenel, Priestley, &c.

It seems most probable, that the blood, during its circulation through the lungs, becomes combined with oxygen; that this oxydated blood, on its return to the heart, is circulated by the arteries to all parts of the body; and that during this circulation, its oxygen is extracted from it, by those parts of the body with which it comes in contact: it is then brought back to the heart by the veins, of a dark colour, and deprived of the greatest part of its oxygen. The effects of oxygen on the blood are well illustrated by what takes place while an animal is drowning. The oxygen is gradually subtracted from the blood, during its circulation, and there

there being no means by which that fluid can recover this principle, its colour gradually becomes darker, till both the arterial and venous blood is become almost black. Along with this abstraction of oxygen, the animal becomes more and more feeble, and in a few minutes dies. If immediately before death, the lungs be laid open, that we may observe what takes place, and if a quantity of oxygen gas be injected through the wind-pipe, we immediately see that the blood acquires a red colour, and circulates towards the heart; which organ, as soon as the oxydated blood arrives at it, recovers its irritability, and by contracting, circulates the blood as usual.

Hence it would seem, that the production of animal heat is not the most important office of respiration; for it is not improbable that irritability, or the vital principle, is continually communicated to the body by these means.

That this is the case would appear from several experiments made by Dr. Girtanner, and from the accurate observations of Lind and Trotter, on the cases of scorbutic patients, as well as the *blue boy* mentioned by Dr. Sandifort; in all which it appears, that a diminution of oxygen is accompanied by a  
diminution

diminution of irritability, or excitability, and that this irritability is restored by restoring the oxygenous principle.

How multiplied and important are the parts acted by this principle on the theatre of nature ! When combined with hydrogen, it forms water ; in its union with combustible bodies, it gives out heat and light, without which we should not be able to perform the most important operations of life : it likewise forms different acids of the greatest utility in the arts. When received by animals into the lungs, it is the cause of their heat, and supplies them with irritability.

The irritability thus supplied by the lungs, is continually wasted by muscular exertion, and the action of different stimuli. This has been ingeniously shown by Dr. Brown, and as it is a subject of great importance in the philosophy of living matter, it may not be improper to point out some of the laws by which living bodies are governed.

I. Living bodies, besides their organization, differ from dead matter, in the property of being acted on or excited by external powers, in such a manner as to produce the living functions ; they must therefore



therefore possess some property distinct from dead matter, which renders them capable of being thus acted on by external powers.—This property has been called *excitability*, or *irritability*.

II. When the powerful action of the exciting powers ceases for some time, the excitability accumulates, or becomes more capable of receiving their action, and is more powerfully affected by them. If the action of the different exciting powers which support life be examined, we shall find abundant confirmation of this law. If light, heat, food, &c. be withdrawn for some time, they act much more powerfully when applied again.

III. When the exciting powers have acted with violence, or for a considerable time, the excitability becomes exhausted, or less fit to be acted on. The truth of this law may be proved by a similar induction.

This exhaustion of the excitability may be either finite, or temporary. When the exciting powers are continually and violently applied, they entirely exhaust the excitability, and produce death; but we find that this principle may be exhausted for a time, and accumulated again. When we have  
been

been engaged in any exertion, either mental or corporeal, for some hours only, we find ourselves fatigued, and unfit to pursue our labours much longer; if now some of the exciting powers be withdrawn, and if we are laid in a posture which does not require much muscular exertion, we soon fall into that state which nature intended for the accumulation of excitability, and which we call sleep. In this state many of the exciting powers cannot act upon us, unless applied with some violence, and we are insensible of their moderate action.

When the action of these powers has been suspended for six or eight hours, the excitability is again capable of being acted on, and we rise fresh and vigorous, and fit to engage in our occupations.

From what has been said, it is evident, that there are three states in which living bodies exist.—1. A state of accumulated excitability.—2. A state of exhausted excitability.—3. When it is in such a state as to produce the strongest and most healthy actions, when acted on by the external powers. It appears likewise, that life depends on the action of external powers on the excitability; and that by their continued action, if they be properly regulated,

ed, the excitability will be gradually, and as it were insensibly exhausted, and life will be resigned into the hands of him who gave it, without a struggle, and without a groan. But as it often happens that we have not the power of regulating the action of these powers, and frequently neglect it when we have; those deviations from the third state, called diseases, take place, which it is not our business to consider in this course of lectures.

## LECTURE



## LECTURE XIII.

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**HYDROGEN**, combined with caloric, forms hydrogen gas ; this substance, which was formerly called inflammable air, was discovered by Mr. Cavendish in the year 1767. Its base is called hydrogen, because it is one of the component parts, or more properly the base of water. It may be procured from several substances, of which it forms a constituent part, but is obtained in the most pure state from the decomposition of water by means of metals.

Metallic substances will not decompose water while cold, unless assisted by an acid, in which case the water is very readily decomposed; its oxygen, oxydating the metal, and the hydrogen flying off in the form of gas.

M. Lavoisier

M. Lavoisier has proved, that when 85 parts of oxygen gas are burned with 15 of hydrogen gas, both gases vanish, and 100 parts of water are formed; and if 100 parts of water are made to pass through a red hot iron tube, 15 parts of hydrogen gas will be procured, while the inside of the tube will be found converted into an oxyd, and to have gained 85 parts in weight.

Hydrogen gas is combustible in an eminent degree; yet it will not burn, unless in contact with oxygen. When pure, and in contact with atmospheric air, it burns with a lambent flame. It burns rapidly when intimately mixed with atmospheric air, in such a manner that each particle of hydrogen gas may be surrounded by particles of atmospheric air. Fire works without smoke or noise, are made by means of hydrogen gas. It is about twelve times lighter than common air, and on this property depends the principles of aerostation. Charcoal, when ignited, will decompose water, but the hydrogen gas procured in this manner is never pure, being always mixed with carbonic acid gas. These gases, though possessed of very different specific gravities, do not easily separate from each other, but form by the attraction of their particles, a compound elastic fluid called hydrocarbonic

bonic gas. It is this aeriform fluid which floats frequently on marshes, and being set on fire by electricity, or other means, gives rise to the *ignis fatuus*.

Hydrogen gas is improper for respiration. An animal immersed in it is killed in the same manner as when immersed in azotic gas. This however does not seem to depend upon any positive noxious quality which this gas possesses, but merely on its excluding oxygen gas. When hydrogen gas is mixed with about one-third of its quantity of oxygen gas, it may be breathed without inconvenience.

Hydrogen gas is frequently found in great abundance in coal mines; where it is sometimes generated suddenly, and becomes mixed with the atmospheric air of these subterraneous cavities. If a lighted candle be brought in, this mixture often explodes in the most violent manner. It is called by miners the fire-damp. Methods have however been contrived to prevent its dreadful effects.

Hydrogen gas is capable of dissolving some combustible bodies, particularly sulphur and phosphorus; and when united to these, it seems to acquire new properties. When united to sulphur it forms



forms sulphurated hydrogen gas, or that fluid which is contained in considerable quantity in sulphurous mineral waters. This gas blackens metallic substances, is very soluble in water; is unfit for respiration; and turns vegetable blues green.

The union of hydrogen gas and phosphorus is called phosphorated hydrogen gas. This elastic fluid has a very foetid smell, is improper for respiration, and takes fire spontaneously on coming in contact with the air, accompanied with an explosion. It is probably to a disengagement of gas of this kind, that we ought to attribute the *ignes fatui* which play about burying grounds, and in general about places where animals are putrifying.

There is probably a stratum of hydrogen gas in the superior regions of the atmosphere, the union of which with oxygen will form water, and may produce meteors.

## LECTURE

## LECTURE XIV.

WE have seen that the atmosphere is composed of two gases or elastic fluids, the first which is called oxygen gas, constitutes nearly one-fourth of the atmosphere; the latter about three-fourths. The first is composed of light, caloric, and oxygen; the latter also is composed of caloric, and a particular base, capable of becoming solid, called azote.— This substance united to different bases, forms alkalies, and hence may be looked upon as a real alkaligen, or alkalizing principle, in opposition to oxygen, which is the principle of acidity. The atmosphere therefore is an immense reservoir of the principles of acidity and alkalescency, without being itself either acid or alkaline.

Azotic gas may be obtained pure by various means; particularly by exposing certain substances

to

to atmospheric air, which absorb its oxygen. As it has been proved that azote united with hydrogen forms ammoniac, or the volatile alkali, and as it is highly probable that the other alkalies are composed of earthy bases united to this substance, it will be necessary here to consider the properties of the different alkalies.

The general properties of alkalies are the following :

1. Their taste is acrid, burning, and urinous.
2. They change the blue colours of some vegetable infusions to green.
3. When mixed with stony substances, and exposed to a considerable heat, they form glass.
4. They render oils miscible with water; effervesce with some of the acids, and form neutral salts with all of them.

Alkalies are divided into fixed and volatile.—  
There are two species of fixed alkali: the vegetable alkali, or potash, and the mineral alkali or soda.—  
The vegetable alkali may be extracted from various substances



substances, but chiefly from the ashes of vegetables and tartar; when purified, it is generally known under the name of salt of tartar.

The mineral alkali, or soda, is the base of sea salt. It may be procured from this salt by various means, but is most usually procured from the ashes of marine plants. This alkali differs from the vegetable in the following particulars.—1. It is less caustic.—2. It effloresces in the air instead of attracting moisture from it.—3. It forms octoedral instead of quadrangular crystals.—4. It forms different neutral salts with the same acids.

These alkalies, in the state we generally meet with them in commerce, are not pure, but really neutral salts, being combined with the carbonic acid; and it is only by a particular management that we can procure them in a pure and uncombined state. The carbonic acid may be separated from them, by presenting to them any substance which has a stronger attraction for that acid.—The alkalies thus freed from carbonic acid are said to be caustic. In this state they unite readily with fats and oils, and form soap. The fixed alkalies combine with sulphur by fusion, and form sulphurets

fulphurets. These alkaline fulphurets dissolve metals, even gold itself.

From the experiments of Thouvenel and Chap-  
tal, on the formation of nitre, as well as some others  
lately made with the oxygenated muriat of potash;  
there is reason to conclude that the combination of  
azote with lime, forms potash, while its union with  
magnesia forms soda.

The volatile alkali, or ammoniac, is distinguish-  
ed from the fixed alkalies, by its penetrating odour,  
and remarkable volatility. This alkali is obtained  
in great abundance from animal substances, and  
particularly from the horns: but the greatest part  
of the volatile alkali in use is produced from the  
decomposition of sal ammoniac, or the muriat of  
ammoniac, by distilling this salt in contact with  
some substance, which by its superior affinity dis-  
lodges the volatile alkali from the muriatic acid.  
When quicklime is used for this purpose, the vola-  
tile alkali is obtained in the form of gas and caustic.  
From several experiments made by M. Ber-  
tollet and Dr. Austin, it has been proved that am-  
moniac is composed of hydrogen and azote. Ac-  
cording to the analysis of the former, 1000 parts  
of ammoniac are composed of 807 of azote, and

193 of hydrogen. Azote combined with oxygen forms the nitric acid, but before we examine its nature, it will be best to take a view of the general properties of acid bodies, which will be found to be the following—

1. They excite a particular sensation on the palate which we call sour.

2. They change the blue colours of vegetables into red.

3. All of them, excepting the carbonic acid, effervesce with the mild alkalies.

M. Lavoisier has proved, by an accurate analysis of the greater part of known acids, that oxygen forms the principle of all, and that their difference from each other depends on the substance combined with the oxygen. The adhesion of oxygen to the base is more or less strong in different acids, in consequence of which they are more or less easily decomposed.

It has been proved both by analysis and synthesis, that the nitric acid is composed of four parts of oxygen, and one of azote, chemically combined.

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This acid corrodes and dissolves with great avidity copper, iron, zinc, tin, and some other metals; and in these operations becomes decomposed; its oxygen oxydates the metal, while the azote, still combined with a small portion of oxygen, forms nitrous gas, or gaseous oxyd of azote.

This acid is never found pure, but always in a state of combination, most commonly with potash, forming nitrat of potash, or common nitre. From this salt it is extracted for use, by means of the sulphuric acid, which disloges the nitric acid from the alkali, by its greater affinity. What remains in the retort is sulphat of potash; the nitric acid passes over into the receiver, and is purified if necessary by various means.

## LECTURE

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## LECTURE XV.

**NITRIC** acid acts powerfully on inflammable and metallic substances, and during this action it becomes decomposed; a part of its oxygen unites with the inflammable substance, while the azote, united to a smaller portion of oxygen, flies off in red fumes, which may be received under a pneumatic apparatus, being the gaseous oxyd of azote, or what has been generally called nitrous gas. This gas is somewhat lighter than common air, and is improper for respiration and combustion. Oxygen gas combines with it very rapidly, converting it into nitric acid; atmospheric air produces the same effect, but more slowly. This combination of oxygen and nitrous gas, presents many important and interesting phenomena. The more pure the air is, the more rapid and remarkable are these phenomena; and on this principle has been contrived an eudiometer,

meter, or instrument for ascertaining the purity of the atmosphere. When azote is combined with a small portion of oxygen, it forms this gas, when more oxygen is added, it forms the fuming nitrous acid, and when fully saturated with this principle, nitric acid is produced.

Nitric acid combines with various substances, forming salts, which are called nitrats: those formed by the nitrous acid being called nitrites. The most important combination is the nitrat of potash, or common nitre. This salt is produced in considerable quantity in many parts of the world, by exposing putrifying animal substances in contact with lime. The lime uniting with the azote of the animal substance, probably forms potash; and the combination of the azote from the same source, with the oxygen of the atmosphere, produces nitric acid. A considerable part however of the nitric acid thus formed, is combined with lime, which base is exchanged for an alkaline base to convert it into nitre. It is afterwards purified by solution and crystallization.

When nitrat of potash is distilled in a red heat, 12000 cubic inches of oxygen gas may be procured from a pound of it. One hundred parts of this salt



salt are composed of thirty of nitric acid, sixty-three of potash, and seven of water.

If seventy-five parts of nitre, nine and a half of sulphur, and fifteen and a half of charcoal, be mixed together, it forms gunpowder; the effects of which depend on the rapid and instantaneous decomposition of the nitre, and the combustion of the sulphur and charcoal by means of its oxygen.

The nitric acid combined with the mineral alkali forms nitrat of soda, and with ammoniac, nitrat of ammoniac; salts which are not much known.

Charcoal is placed among the elementary bodies, because we have not yet by any means been able to decompose it. It forms the skeleton of vegetables, or their woody fibre. The microscope discovers a surprizing number of pores in charcoal, Dr. Hook calculated that a piece of charcoal of an inch in diameter, contains no less than 5,724,000 pores. It is to this porosity that the blackness of charcoal is owing, and through these pores the vegetable juices circulate.

Charcoal is very incorruptible, and on that account

count, the lower parts of posts used in paling, are charred to preserve them.

The charcoal is procured by heating wood in so slow a manner that the oily and watery parts are driven off in vapour, while the carbon, which cannot be reduced to vapour by heat, remains, preserving the exact form of the vegetable.

The very light charcoals of linen, cotton, and some fungi, readily catch fire from a spark; these substances are called tinder. Charcoal is much used in chemistry, and in several of the arts. It is one of the most powerful antiseptics with which we are acquainted. Hence, it preserves water from putrefaction, and restores its sweetness, after it has become putrid. It preserves meat, and will render brown rancid oils sweet and clear, which effects are produced by its strong affinity for oxygen.

If by any means, large quantities of vegetable matters are buried at some depth under ground, or kept for a long time from contact with the atmosphere, the aqueous and oily parts will be dissipated, and the vegetable fibre will remain in the form of a charcoal, mixed with more or less sulphur, which is contained in all vegetables. The immense

menſe quantity of leaves, and other vegetable matters that are continually waſhed down rivers, will be collected in beds at the bottom of the ſea, and there become charred; and being reduced into a minute ſtate by attrition, and other circumſtances, inſtead of preſerving the appearance of vegetables, they reſemble foſſils, and form beds of coal.

## LECTURE



## LECTURE XVI.

**WHEN** charcoal is burned in a quantity of oxygen gas, exactly sufficient for its combustion, both the charcoal and oxygen gas disappear, and a quantity of elastic fluid is found in the vessel, which is equal in weight to both the charcoal and oxygen gas.

This elastic fluid is manifestly acid, and being composed of carbon and oxygen, it is called in the new Nomenclature, the carbonic acid. We are indebted to Dr. Black for our knowledge of some of the most remarkable properties of this fluid; he was the first who discovered the affinity between this gas and alkalies, quicklime, and magnesia.

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This substance has received different names from different chemists. Dr. Black called it fixed air, which Macquer observes is by no means a proper name for it; he called it mephitic air, but this is not by any means peculiarly characteristic. Bergman called it aerial acid, and it has likewise been called the cretaceous acid, or acid of chalk, because it is contained in large quantity in that substance.

This acid exists in three different states; in a state of combination, in the state of gas, and in that of mixture. It is combined with calcareous earth or lime, for which it has a greater affinity than for any other. It constitutes nearly half the weight of chalk, limestone, marble, &c. converting them into saline substances or carbonats. It may be procured from these substances by two different methods, namely, by heat, or the affusion of acids. The first is done in burning lime; the carbonic acid combines with caloric, and flies off in the form of gas, leaving the calcareous earth pure. If a quantity of chalk be put into a retort, and sulphuric acid poured upon it; the carbonic acid may be expelled in the form of gas, and is found to be possessed of the following properties. First, it extinguishes flame, and kills animals immersed in it. Second, its specific gravity is much greater than that

that of common air, on this account it occupies the lowest part of the atmosphere, and may be poured out of one vessel into another like water.

This gas is emitted in large quantities by fermenting liquors, being often generated plentifully in coal mines, and is instantly fatal to the miners, who call it the choak, or chalk damp. Wells which have been long shut up, are often found filled with this gas, and therefore workmen should never enter them without proper precautions. There are methods however by which both coal pits and wells may be purified.

There are some natural caverns in which this gas is produced in considerable quantity, and runs out at the opening like a stream of water; this is particularly the case with the celebrated grotto *del cano*.

Charcoal should never be burned in rooms that have no fire place, or vent, because the red hot charcoal unites with the oxygen of the atmosphere, and forms carbonic acid, which cannot escape without a ventilator. Some melancholy accidents have happened from this cause.

Water



Water absorbs more than its bulk of this gas at a mean temperature, and acquires an acid taste, and sparkling appearance, like some of the mineral waters. Various methods have been contrived for impregnating water with this gas, but the machine invented by Dr. Nooth, is by much the most convenient and elegant. Most mineral waters owe their sharp spirituous taste to this gas. Water thus impregnated is capable of dissolving a small quantity of iron, and forms an elegant chalybeate, similar to some of the natural chalybeates. When fixed alkali is previously dissolved in water, it will then absorb a much greater quantity of carbonic acid than common water, forming the aqua mephitica alkalina, which is so useful in calculous complaints. This is likewise the best way of giving effervescing draughts. Carbonat of lime cannot be dissolved in water, except in very small quantity, but pure lime can be dissolved in considerably greater weight, forming lime water, which is an excellent test of the presence of carbonic acid; for it is instantly precipitated by that acid in the form of carbonat of lime. By this mean we also prove that the air which comes from the lungs contains carbonic acid.

But though water will only dissolve a very small  
portion

portion of carbonat of lime, yet if the water be saturated with carbonic acid, it will then dissolve carbonat of lime in considerable quantity. If this solution be let fall, drop by drop, on any substance, as the carbonic acid escapes, the carbonat of lime will be deposited upon the substance, which will in this manner become encrusted with a coat of calcareous earth. In this state the substance has been called petrified.

Cyder, beer, and other fermented liquors, owe their briskness to the carbonic acid which they contain.

Many chemists supposed that carbonic acid was composed of vital air and phlogiston; but as the science of chemistry advanced, it was proved by Lavoisier, that the charcoal of wood combined with vital air, and formed carbonic acid. With this synthetic proof the French chemists were contented; it was afterwards demonstrated analytically by Dr. Tennant, who showed that charcoal and phosphoric acid were produced, by applying phosphorus to red hot marble; from which he inferred, that the carbonic acid of the marble was decomposed; its oxygen uniting with the phosphorus, formed phosphoric acid, while the carbon was left uncombined.

LECTURE

## LECTURE XVII.

**SULPHUR** is a very combustible substance, dry, brittle, and of a fine yellow colour. It has no smell excepting it be warmed, when it sends forth a peculiar though weak odour. If it be rubbed it becomes electrical, and a roll of sulphur grasped in the hand, breaks with a crackling noise.

Sulphur is found in great quantity in nature, sometimes in a state of purity, but most commonly combined with some of the metals. It is frequently formed by the decomposition of animal and vegetable substances; and particularly where large quantities of vegetables are putrefying.

A moderate degree of heat is sufficient to melt sulphur, and if at the instant when its surface begins to congeal, the liquid sulphur under the surface



face be poured into another vessel, it will form crystals.

Sulphur unites with most of the metals, and renders them very brittle and fusible: most of the imperfect metals are indeed found combined with sulphur, or mineralized by it, as it is termed; the metal is freed from the sulphur by roasting, before it is smelted. Sulphur unites with iron when that metal is red hot, and forms a hard compound; and this furnishes us with an easy and excellent way of fastening pieces of iron in stone.

Sulphur, like all combustible bodies, only burns in proportion to the quantity of oxygen which combines with it; and the products of this combustion vary according to the proportion of oxygen combined with the sulphur; if only a small quantity of oxygen be combined with it, a volatile and penetrating acid is formed, called *sulphurous acid*; but if the combustion be carried on rapidly, so that a greater quantity of oxygen may be combined with the sulphur, a ponderous acid is formed called the *sulphuric*.

The characters of this acid are the following, First, it is unctuous and greasy to the touch. Second,

cond, its specific gravity is much greater than that of water. Third, when mixed with an equal quantity of water, a degree of heat is produced greater than that of boiling water.

Concentrated sulphuric acid exposed to cold, concretes, and may be obtained in a crystalline form. The sulphuric acid is used in several of the arts and manufactures.

This acid united to potash, forms a neutral salt called sulphat of potash. One hundred parts of this salt contain thirty of acid, sixty-five of alkali, and five of water.

This acid combined with the mineral alkali forms sulphat of soda, which may be procured in beautiful crystals, and is commonly known by the name of Glauber's salt. One hundred parts of this salt contain fourteen of acid, twenty-two of alkali, and sixty-four of water. With the volatile alkali, the sulphuric acid forms a neutral salt, called the sulphat of ammoniac, which crystallizes with difficulty, and is little known.

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## LECTURE XVIII.

**PHOSPHORUS** is one of the most curious substances in chemistry ; the discovery of it is attributed by Leibnitz to Brandt. He made this discovery in the year 1667, and communicated it to Kraft, who imparted it to Mr. Boyle.

It appears that Kunckel and Kraft had agreed to purchase the secret from Brandt, but Kunckel having been deceived by Kraft, fell to work himself, and discovered a way of making this substance, which he published, and from that time it has generally gone by his name.

For some time phosphorus was made in very inconsiderable quantities, the operation being tedious and disagreeable, consisting in evaporating large quantities



quantities of urine. Various methods were taken to shorten the operation, and render the process less disagreeable, but to little purpose; the best account of this method of making phosphorus was published by Margraff, in the Berlin Memoirs.

In 1769, Monsieur Gahn discovered, that the earth which remains after the calcination of bones, consists of phosphat of lime, and Scheele proved, that by mixing this phosphat of lime with the nitric or sulphuric acids, these acids, by their superior attraction, combined with the lime, and expelled the phosphoric acid; and by distilling this acid with powdered charcoal, he obtained phosphorus. The process is very well described in Chaptal's elements of chemistry.

Since this time, phosphorus has generally been extracted from the earth of bones, and the making of it is by no means so difficult an operation as formerly.

In whatever manner phosphorus is made, it is always the same substance. It is generally of a flesh colour, and transparent when pure; is of the consistence of wax, and may be cut with a knife.—When it comes in contact with the air it emits a white smoke, and its surface appears luminous in

the dark. When exposed to the atmosphere, and heated to about 86 degrees of Fahrenheit's scale, it takes fire, and burns with great rapidity; what remains after the combustion is of a red colour, attracts humidity from the air, and becomes liquid: this liquid is the phosphoric acid which will soon be noticed.

If we write with phosphorus upon any solid body, the characters become luminous in the dark.— Various contrivances have been made for lighting a candle by means of phosphorus, such as the philosophical fire-bottles, and phosphoric bougies; but the phosphoret of lime seems best to answer this purpose.

Phosphorus is capable of being dissolved by various liquids; such as alcohol, ether, and oil, which it renders luminous. The phosphoric oil, or liquid phosphorus, as it is generally called, may be rubbed upon any part of the body without danger, and renders that part luminous in the dark. The light produced by this solution of phosphorus in oil, very much resembles that of the glow-worm.

Putrifying animal substances generally emit a phosphoric light, and particularly fish; rotten wood often does the same. If

If phosphorus be heated to about 84 degrees, and plunged in pure oxygen gas, it burns with great brilliancy; during this combustion the oxygen is absorbed, and a quantity of acid liquor formed, which is equal in weight to the quantity of oxygen and phosphorus consumed. Lavoisier, and De la Place, have found that forty-five grains of phosphorus, during their combustion, absorb sixty-five grains of oxygen.

Phosphorus unites with oxygen in three different ways. First, by a rapid combustion and deflagration. Second, by a slow combustion. Third, by a decomposition of bodies which contain oxygen.

The phosphoric acid combines with a variety of substances, particularly lime, and the alkalies.— With lime it forms phosphat of lime, or earth of bones, which is sometimes found in nature in large quantities; entire rocks being composed of it.— With potash this acid forms a salt capable of crystallization, called phosphat of potash, which is very little known. With soda it forms a salt, which may be procured in beautiful crystals, called phosphat of soda, but better known by the name of



of tasteless purging salt; it is chiefly used as a laxative.

Phosphoric acid unites with ammoniac, and forms phosphat of ammoniac, a salt which is sometimes found in putrifying animal substances, but is very little known.

## LECTURE

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## LECTURE XIX.

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**THE** muriatic acid, or spirit of salt, as it is commonly called, is very abundant in the mineral kingdom, being naturally combined with different bases, particularly with soda, lime, and magnesia. This acid is never found pure or uncombined, and in order to obtain it in this state, we must disengage it from other substances, with which it is in combination. It is most usually disengaged from common salt, by means of the sulphuric acid, which having a greater affinity for the soda, the muriatic acid is expelled in the form of gas, and is absorbed by the water in the receiver. Wolfe's apparatus is the best for this purpose.

Though in the new Nomenclature, the muriatic radical is put down among the acidifiable bases, yet the muriatic acid does not appear to have been decomposed

decomposed in any chemical experiment : so that we have no idea whatever of the nature of this radical, and only conclude from analogy that oxygen is its acidifying principle.

The muriatic acid is more light and volatile than the sulphuric, and has a weaker affinity for earths and alkalies. It differs from the nitric acid in its colour, being of a yellowish green, while the latter is generally of an orange colour.

The muriatic acid combines with potash, and forms a salt called muriat of potash, formerly known by the name of febrifuge salt of Silvius. The crystals of this salt are not cubic, like common salt, but parallelopedids. One hundred grains of this salt contain thirty of muriatic acid, sixty-four of potash, and six of water.

The muriatic acid forms with soda a neutral salt called muriat of soda ; this combination is the common alimentary salt, the taste of which is well known : it decrepitates when thrown upon hot iron, and is nearly equally soluble in cold and hot water. One hundred parts of this salt contain thirty-four of acid, fifty of alkali, and sixteen of water. The figure of its crystals is perfectly cubic. It is usually procured from



from sea-water, and salt-springs, and exists in various parts of the world in the form of fossil or rock salt. This salt is of three kinds, namely, rock, or native salt, bay salt, and white salt. The first is dug out of mines, the second is procured from sea water evaporated by the sun, and to obtain the last, sea water is evaporated by boiling.

The muriatic acid combines with the volatile alkali or ammoniac, forming the muriat of ammoniac. This is the most useful and interesting of all the combinations with ammoniac, and is known by the name of crude sal ammoniac. This salt is much used in the different arts, and has the property of making tin unite very readily with iron and copper. It is usually brought from Egypt in semi-transparent cakes, but some manufactories of it have lately been established in Europe, these have however been kept secret. One hundred parts of this salt contain fifty-two of acid, forty of ammoniac, and eight of water.

This salt may be decomposed both by acids and alkalies; the sulphuric and nitric acids unite with the ammoniac, and disengage the muriatic acid. The fixed alkalies and lime have a greater affinity  
for

for the muriatic acid than the ammoniac has, and will therefore decompose this salt.

The muriatic acid is capable of combining with a much greater quantity of oxygen than it possesses in the state of common muriatic acid, and what is remarkable, it becomes more volatile, while the other acids, when super-oxygenated, become more fixed. In this state likewise its powers as an acid are weakened, for it has a much weaker affinity for alkaline salts, and will not even redden the blue colours of vegetables, on the contrary, it destroys these colours. The acid in this state is called the oxygenated muriatic acid. The muriatic acid seizes oxygen with great avidity, yet so weakly does it hold it in union, that it may be expelled by a very moderate degree of heat, or even by exposure to the rays of the sun. This acid is procured by distilling common muriatic acid from the oxyd of manganese, by means of Wolfe's apparatus; the acid attracts the oxygen of the manganese, and flies off in the form of gas, which is readily absorbed by water.

When oxygenated muriatic acid is mixed with caustic or pure ammoniac, a quantity of water is formed, and azotic gas is disengaged, the acid returning

turning to the state of common muriatic acid. In this experiment the oxygen of the acid combines with the hydrogen of the ammoniac, and forms water.

The oxygenated muriatic acid forms with potash a beautiful white salt called the oxygenated muriat of potash. The oxygenated muriatic acid which exists in this salt, contains much more oxygen than when in a liquid state, and the oxygen is very loosely attached, being separable by mere heat. From one hundred grains of this salt may be procured seventy-five cubic inches of extremely pure oxygen gas. A small quantity of this salt rubbed in a mortar with flowers of sulphur, explodes, and still more violently with phosphorus.

If this salt be used instead of nitre, a gunpowder will be formed much more powerful in its effects than common gunpowder.

If the muriatic acid be combined with the nitric, an acid is formed, which has different properties from either of its component parts; this acid is called in the new Nomenclature the nitro-muriatic acid, and was formerly known by the name of aqua regia.

Berthollet



Berthollet thinks, that in this case the acidifyable bases combine, and form a single acid different from all others; but Chaptal is of opinion, that in this operation the muriatic acid becomes oxygenated by seizing the oxygen of the nitric acid, and this on several accounts seems most probable.

## LECTURE

## LECTURE XX.

THE principal vegetable acids are the acetous and the tartarous ; the former is known by the name of vinegar, and is formed by the oxydation of vinous liquors, generally by exposing them to the atmosphere. It appears in the form of an acid liquor, more or less deeply tinged ; by distillization it is separated from its impurities, and is then transparent and colourless ; when concentrated, which it may be by various methods, it is called radical vinegar. The acetous acid produces neutral salts by combining with different substances. With potash it forms acetite of potash, commonly called diuretic salt, which may be procured in fine crystals, but is very deliquescent. The acetite of soda is likewise deliquescent, but very little known. The acetite of ammoniac is extremely deliquescent, and is known in medicine by the name of spirit of Mindererus.

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The radical of the acetous acid is carbon, hydrogen, and a little azote.

Several vegetables, as lemons, forrel, and un-ripe fruit, contain acids ready formed by nature, which consist, like the acetous acid of compound radicals, differing only in the proportions of those substances which compose the radical. These acids may be concentrated by freezing.

Sugar, and the farinaceous vegetables, consist of hydrogen, carbon, and a little oxygen. If these substances be combined with more oxygen, an acid may be procured in crystals resembling the acetous acid in taste, but differing from it in some other properties. This acid is called acid of sugar, or oxalic acid, and is generally made by oxydating sugar by means of the nitric acid.

The acid of sugar unites with alkalies, earths, and metals, and gives the name of oxalat to the combination. The most curious fact relative to this acid is, that it attracts lime more powerfully than any other acid, forming with it a compound nearly insoluble; on this account it is an excellent test of the presence of lime. The acid of sugar takes spots, and particularly iron-moulds, out of linen. The mallic and citric acids are only varieties of this acid.

Wood



Wood, when burned or distilled, yields a particular acid, called the pyroligneous acid, which is used by callico printers to dissolve iron.

If tartar be dissolved in water by boiling, and the clear liquor suffered to crystallize, beautiful crystals may be procured, which have been called cream, or crystals of tartar, but according to the new Nomenclature, acidulous tartarite of potash, for they consist of potash super-saturated with a particular acid called the tartarous.

The acidulous tartarite of potash is capable of combining to saturation with potash, and forms a neutral salt, the tartarite of potash, which has commonly been called Rochelle salt.

The radical of the tartarous acid is like other vegetable acids, composed of hydrogen and carbon.

The bark of oak, and other astringent vegetables, but particularly the gall nut, contain a substance which has been called the astringent principle; it has lately been discovered to be a peculiar acid, and is called the gallic acid. This acid has a stronger attraction for metallic oxyds, than any other acid; it precipitates iron from its solution in  
the

the form of a fine dark blue, or black powder; which, suspended in water by means of gum, makes the common writing ink.

The gallic radical is not known, but it may be changed into the oxalic acid by means of the nitric, and is supposed to consist of carbon and hydrogen.

If amber be distilled in close vessels, there sublimes from it a peculiar acid called the succinic acid. The compounds formed by this acid with different substances, are called succinats.

Borax is composed of soda, and a peculiar acid called the boracic acid; this acid may be procured from borax by means of the sulphuric, and has been called sedative salt. The combinations of this acid with different substances, are called borats, but are little known, excepting the borat of soda, or common borax, which is very useful in some of the arts. The boracic radical is not known.

Fluor-spar is composed of lime, or calcareous earth, combined with a peculiar acid called the fluoric acid. This acid may be procured from the spar by means of the sulphuric. The fluoric acid should be kept in leaden vessels, as it dissolves glass very

very readily. This property affords an easy method of etching on glass. The name of fluat is given to the combinations formed by this acid with different substances; we are however little acquainted with any of these combinations excepting fluat of lime.

If dried blood be mixed with potash, and exposed to a red heat for some time, a peculiar acid unites with the potash, called the prussic acid, and the combination which was formerly known by the name of phlogisticated alkali, is called prussiat of potash.

The prussic acid precipitates the metallic oxyds from their combinations with other acids. Iron is precipitated by this acid in the form of a beautiful blue powder, commonly called prussian blue, but in the new Nomenclature, prussiat of iron. The prussiat of potash is a very delicate test of the presence of iron.

The radical of the prussic acid is supposed to be composed of carbon and azote, with a small quantity of hydrogen.

There



There are several other acids, but they only differ from those we have considered, in the proportions of the component parts of their radicals. They are generally convertible one into the other, and their compounds are of little consequence.

## LECTURE

## LECTURE XXI.

**THOUGH** there seems to be an almost infinite variety of earthy substances scattered on the surface of this globe; yet when this subject is examined with a chemical eye, we shall find, not without surprize, that all the earths and stones which we tread under our feet, and which compose the largest rocks; and that the vast variety of specimens which adorn the cabinets of the curious, are composed of a very few elementary earths, scarcely exceeding five in number.

Of these five elementary earths, two are in some measure more dry, hard, insipid, and insoluble; while the other three possess saline properties, which render them akin to the substances denominated alkalies. These three, which have in consequence

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been

been termed salino-earthly, and alkaline earths, are *barytes*, *magnesia*, and *lime*. The other two are, *silex* and *alumin*. Some other earths have been lately discovered, but they are found in very small quantity, such as the adamantine earth, and jargon.

All the earthy and stony substances we meet with are composed of some or all of the five earths just enumerated. Their general character is dryness, indestructibility, and infusibility, besides which, each has specific characters.

*Silex* is rough to the touch, cuts glass, and scratches or wears away metals; its weight is about  $\frac{2}{5}$  that of an equal bulk of water. It is infusible, incombustible, and insoluble in most acids; but soluble in alkalies with the assistance of heat, forming glass. It is found in great abundance in sand, quartz, flint, agate, grit, and almost all stones that strike fire with steel.

*Alumin*, or argil, is soft to the touch, adheres to the tongue, and hardens in fire, contracting in its dimensions, and when exposed to an extreme heat, it becomes so hard as to strike fire with steel.

When mixed with water and *silex* in proper proportions,



proportions, it forms porcelain; it constitutes the greatest part of clays, schists, steatites, &c. and forms the basis of all kinds of earthenware.

With the sulphuric acid it forms sulphat of alumin, a salt much used in different arts under the name of alum, of which there are two different kinds, the common and roch alum, which do not however differ in their chemical properties. This salt has a strong styptic taste, and is evidently supersaturated with the sulphuric acid. It dissolves in fifteen times its weight of cold water. The combinations of this earth with the other mineral acids are not interesting.

Barytes, or heavy earth, is exceedingly white and pure, and is soluble in about 900 times its weight of cold water, to which it communicates a taste and properties similar to lime-water. Its specific gravity is to that of water as four to one. It is precipitated from its combinations with the different acids by the prussiat of potash, like metals; from these circumstances, there is reason to suspect it to be a metallic oxyd, but chemists have never yet procured it in a metallic or deoxydated form.

The most common form in which we meet with  
this

this earth, is in combination with the sulphuric acid, forming sulphat of barytes, or heavy spar, the specific gravity of which is to that of water as 4.5 to 1. It generally accompanies metallic veins.— This substance is nearly insoluble in water.

With carbonic acid this earth forms carbonat of barytes, which does not appear to exist in great quantity in nature. One hundred parts of carbonat of barytes contain twenty-eight of water, seven of carbonic acid, and sixty-five of barytes.

Barytes forms with the nitric acid, nitrat of barytes, a salt which has never been found native, and is little known.

This earth forms with the muriatic acid, the muriat of barytes, a salt seldom if ever found formed by nature. This salt is one of the best tests of the presence of the sulphuric acid.

Magnesia is never found naturally pure, but generally combined with the sulphuric acid. To procure it pure, it must be precipitated from this combination by means of an alkali.

This earth is extremely white, light, and spungy;

gy: with acids it forms salts, which are extremely soluble, and since it has a weaker affinity for acids than lime, it is easily separated from them by that substance.

With the sulphuric acid it forms sulphat of magnesia, better known by the name of Epsom salt. This salt is found in great plenty in the bitter liquor that remains after the crystallization of common salt, made from sea-water, and the greatest part of the magnesia in use, is procured by precipitating the earth from this salt. One hundred parts of the sulphat of magnesia contain twenty-four of acid, nineteen of earth, and fifty-seven of water.

The nitrat of magnesia is extremely deliquescent. This salt is little known.

The muriat of magnesia is likewise very deliquescent, and remarkably bitter. It is contained in sea water, and in the water of some saline springs.

Carbonat of magnesia, or mild magnesia, is seldom found formed by nature, but obtained by precipitating the magnesia from the sulphat of magnesia by a carbonated alkali. One hundred parts of this salt generally contain thirty of carbonic acid, forty-eight



forty-eight of magnesia, and twenty-two of water. The carbonic acid may be driven off by a violent heat, and the earth which remains is pure or calcined magnesia.

Lime is very seldom found pure, but generally combined, and chiefly with the carbonic acid; it may however be procured pure by expelling the carbonic acid by means of heat. It is soluble in 680 times its weight of water, forming lime water, which has an alkaline taste, and peculiar properties. Pure lime attracts water with great avidity, which becomes fixed or solid in it, and giving out its latent heat, causes the mass to become extremely hot.

The combination of lime with the carbonic acid is by much the most common, and comprehends all those stones or rocks, which are known by the names of chalk or limestone, or under the general name of calcareous earth.

The characters of carbonats of lime are the following—First, they effervesce with acids. Second, they are convertible into lime by calcination. There are many reasons to believe, that nearly all the calcareous earth which we meet with on the surface of the globe, in the form of limestone, chalk, marble, &c.

&c. derives its origin from the destruction of the shells of marine animals. Lime, mixed with sand, and tempered with water, forms mortar. This important cement has been much improved by the researches of Dr. Higgins.

Lime, combined with the sulphuric acid, forms sulphat of lime, gypsum, or plaster of Paris. One hundred parts of this salt contain thirty of sulphuric acid, thirty-two of lime, and thirty-eight of water. This salt is generally formed by the decomposition of pyrites, which happens to be incumbent on beds of calcareous earth. It is soluble in about one hundred times its weight of cold water. It is used for making casts, and ornaments for buildings.

The nitric and muriatic acids form with lime diluquescent salts, which are little known.

The fluoric acid combines with lime, and forms fluat of lime, or Derbyshire spar. Lime is likewise found combined with the phosphoric acid, and this constitutes the earthy part of the bones of animals.

## LECTURE XXII.

**METALS** are substances distinguished by their weight and lustre: they are fusible, crystallisable, and combustible; they decompose water, and several acids, and are converted into metallic oxyds. They have by chemists been generally divided into three classes, semimetals, imperfect metals, and perfect metals. This division, as is properly observed by Fourcroy, has evidently derived its origin from the erroneous ideas of alchemy. He divides metals into five genera: in the first are comprised brittle and acidifiable metals: this genus contains three species, arsenic, tungsten, and molybdena. The second genus contains those which are brittle, and simply capable of oxydation, of which there are five species, cobalt, bismuth, nickel, manganese, and antimony: the third genus includes the semi-ductile and oxydable metals, of which



which there are two, zinc and mercury. The fourth genus contains such metals as are perfectly ductile, but at the same time easily oxydable: such as tin, lead, iron, and copper. The fifth and last genus comprehends those that possess perfect ductility, but which are not oxydable without great difficulty. This genus comprehends three species, silver, gold, and platina.

Though there are various circumstances under which metals may be united with oxygen, they may in general be reduced to three. First, the contact of air, assisted by caloric. Second, by decomposing water. Third, by decomposing acids.

Different metals require different quantities of oxygen to convert them into oxyds; and each metal, separately considered, absorbs different proportions of oxygen, and stops at various points of oxydation, according to the degree of temperature to which it is raised.

Metals differ in their attraction for oxygen. Some have so weak an affinity for that substance, that if their oxyds be simply exposed to the light, the oxygen separates from them; such are gold and silver. Others, as mercury, require for its separation

tion a considerable degree of caloric and light.— Others have so strong an attraction for oxygen, that it cannot be separated from them merely by the action of caloric and light; nothing but the addition of a combustible substance can effect this decomposition.

Metals cannot be dissolved in acids, unless they be previously oxydated, but when the acid is diluted with water, the metal decomposes the water, becomes oxydated, and is then dissolved by the acid. As an exception to this however, it may be observed, that metals can be dissolved in the nitric acid without the addition of water; for they decompose a part of the acid, attract its oxygen, and are then dissolved by the remainder.

Few of the metals, except gold and platina, are found pure, but generally in the form of oxyds, or ores. These metallic ores, excepting those of iron, are never found in regular strata like the earths, but in cavities, or rents, which run among the earthy strata in all directions. From this, and other circumstances, it seems probable that metals are contained in large quantities in the interior parts of the earth, and that, by subterraneous fires, they are forced into rents near the surface.

To

To convert metallic ores into metals, they are first roasted, to drive off the sulphur and arsenic, then fused along with substances capable of attracting their oxygen. The unmetallic parts are vitrified, and float on the surface, while the metal falls to the bottom of the furnace.

We shall now consider each of the metallic substances in the order in which they were enumerated.

Arsenic is a dark coloured metallic substance resembling antimony, but its oxyd is white. This oxyd, which is improperly called arsenic, is soluble in about eighty times its weight of cold water, or fifteen times its weight of boiling water. Oxygenated muriatic acid digested upon this substance, converts it into arsenic acid, by imparting its superabundant oxygen. The oxyd of arsenic is used in a variety of arts, but is a most deadly poison. The best antidote is the sulphuret of potash, which decomposes the oxyd, and renders it in a great measure harmless. If any substance containing arsenic be mixed with oil, or powdered charcoal, and thrown upon a red hot iron, a smell like that of garlick will be perceived.

Tungsten is of a brownish or black colour, radiated



diated and shining; it is granulated, friable, and almost infusible; scarcely soluble in the acids, but converted into an acid by the action of air and caloric.

Molybdena resembles plumbago in appearance, but in its texture is scaly, and not easily pulverised. By heat it is converted into a white oxyd.

Cobalt is of a grey or steel colour, close grained, difficult to fuse, and not easily oxydated. It is generally however found in the state of an oxyd, mineralized by sulphur and arsenic. The oxyd of cobalt when fused, forms a beautiful blue glass called smalt, which is used in several manufactures.

Cobalt is soluble in the acids, particularly in the state of an oxyd, but does not form any interesting combinations, excepting the solution of it in the nitro-muriatic acid, which forms a curious sympathetic ink.

Bismuth is composed of cubes, formed by the application of plates to each other; it has a redish tinge, particularly when exposed to the air; it is nearly ten times heavier than water, is not malleable, but easily reduced to powder. It is soluble in the

the acids, from which it is precipitated by water alone, in the form of a white oxyd, which is much used as a cosmetic.

Nickel has a redish cast, great hardness, is magnetic, and very infusible. It is soluble in the acids. It is often found mineralized by copper, forming cupfer-nickel; it has not yet been applied to use.

Manganese is of a dull white colour when in its metallic state, but grows black when exposed to the air. Its attraction for oxygen is so great, that it is always found in the form of an oxyd, which is black, hard, and ponderous; it contains nearly half its weight of oxygen, which may be procured from it in the form of gas merely by heat. There is another oxyd of manganese, called black woad, which inflames spontaneously when mixed with linseed oil.

Antimony is of a whitish silvery colour, and scaly texture; it melts soon after ignition, and soon oxydates. It detonates with nitre, and forms oxydated antimoniated potash. It is generally found mineralized by sulphur, in the form of sulphuret of antimony, or crude antimony, which is convertible

ble by heat into a dark coloured glass, commonly called *crocus metallorum*.

This metal is often used in medicine. The preparations at present most used are antimonial wine, and *antimonium tartarizatum*, or emetic tartar. James's fever powder is likewise a preparation of antimony.

## LECTURE



## LECTURE XXIII.

**ZINC** is a metal of a bluish cast, brighter than lead, and so far malleable as not to be broken by a hammer, though it cannot be much extended. It melts long before ignition, and when heated a little above its melting point, particularly if agitated, it burns with a dazzling white flame, and oxydates with great rapidity. The oxyd thus formed is volatile, and condenses into a flocculent mass, which has been called flowers of zinc, or philosophical wool.

This metal is very volatile; it is generally found mineralised by sulphur in the ore called blend: there is likewise another one of zinc, called calamine. It is generally found mixed with more or less lead, and sometimes in such quantity in the East Indies, that it is fused in that state, and forms the

the metallic compound known by the name of Tutenag. Diluted sulphuric acid dissolves zinc rapidly, and a great quantity of very pure hydrogen gas is driven off, which arises from the decomposition of the water. The sulphat of zinc may be procured in white crystals. The muriatic and nitric acids dissolve zinc, but the compounds formed by them with this metal are very little known.

Zinc, precipitated from its solution in the sulphuric acid, in the state of an oxyd, forms a pigment in every respect superior to white lead.

Mercury differs from the other metals in preserving its fluidity in the common temperature of the atmosphere, but if cooled down to  $39^{\circ}$  below  $0$ , it becomes solid, hard, and malleable. This metal is fourteen times heavier than water; it evaporates in low degrees of heat, and boils at about  $600^{\circ}$ .

When exposed to the air, and heated somewhat short of its boiling point, its surface becomes slowly oxydated, forming the red oxyd of mercury; from which the oxygen may be expelled in a very pure state by exposing it to a red heat.

The sulphuric acid when hot, is decomposed by

by mercury, while the metal is converted into a yellow oxyd, which was formerly called turbith mineral.

Mercury dissolves very readily in the nitric acid, oxydating itself by decomposing part of the acid, and the oxyd is dissolved in the remainder.

The muriatic acid unites with the mercury dissolved in the nitric acid, and if the oxygenated muriatic acid be employed, corrosive sublimate is formed, or the oxygenated muriat of mercury; but if the common muriatic acid be used, then the substance formed is muriat of mercury, or calomel.

Corrosive sublimate is soluble in nine times its weight of water, from which it may be precipitated by barytes, magnesia, or lime.

Mercury combines with sulphur by trituration, forming a black powder, which has been called Ethiops mineral. A more intimate combination is formed by heat, which is called cinnabar, which substance powdered, forms vermilion.

Mercury is usually found mineralized by sulphur, in the form of cinnabar; very seldom pure. It readily combines with most metals, forming what is called an amalgam. Looking glasses are covered



ed on the back with an amalgam of mercury and tin.

Mercury is used in various arts, and in medicine.

Tin is a metal of a slight yellow cast, harder than lead, but very malleable, and capable of being extended into thin plates called tin foil. It is the lightest known metal, extremely fusible, and when melted, it oxydates very rapidly. The oxyd of tin is very infusible, and is used to make white opaque enamels. Thin sheets of iron, coated with tin, are used to make a variety of utensils.

Tin readily unites with different metals, and an amalgam composed of two parts of mercury, one of zinc, and one of tin, renders the action of electrical machines very powerful.

Concentrated sulphuric acid, assisted by heat, dissolves tin, but part of the acid is decomposed. If the acid be diluted with water, the oxyd of tin is precipitated. Nitric acid attacks tin violently, part of it is decomposed and oxydates the tin, and the remainder dissolves the oxyd as it is formed.

The muriatic acid also dissolves tin, but the  
nitro

nitro-muriatic acid dissolves it much more readily, forming a gelatinous kind of liquor, the nitro-muriat of tin, which is used by dyers to brighten the colour of some red tinctures. Tin detonates with nitre; and if tin foil be wetted with a solution of nitrat of copper, heat and flame will be produced.

Tin is the principal ingredient in the composition of pewter, the other ingredients are lead, zinc, bismuth, and copper. Tin is also used for coating copper vessels: it is sometimes found native, but generally mineralized by sulphur and arsenic.

Lead has no great tenacity, but very considerable specific gravity; it melts long before ignition, and begins to oxydate. In its first degree of oxydation it is yellow, and has been called massicot; by imbibing more oxygen it becomes red, and is then called minium, or red lead; more properly the red oxyd of lead. If a great heat be quickly applied, this oxyd is converted into litharge, and by a still greater heat into glass.

Lead unites with most metals, but not with iron. Two parts of lead, and one of tin, form soft solder, which melts with less heat than either of the metals; but a composition of bismuth, lead, and tin, in proper

proper proportions, makes a compound so fusible, that it melts in boiling water.

Sulphuric acid will not act upon lead unless boiling; it is then decomposed and oxydates the metal. Nitric acid readily converts it into an oxyd, which is dissolved by the diluted nitric acid, forming nitrat of lead.

The affinity of the muriatic acid for lead is so strong, that this metal decomposes all the muriats; and on this principle, some manufactures for the separation of soda from common salt have been established. The muriat of lead formed in this operation is of a beautiful yellow colour, and used as a pigment. The acetous acid oxydates lead, and forms white lead. All the oxyds of lead are soluble in the acetous acid, and the solution evaporated forms acetite, or sugar of lead. If this acetite of lead be dissolved in water, and the lead precipitated by zinc, it assumes a beautiful ramified appearance.

Lead is sometimes improperly used to sweeten some wines, but may be detected by Hahnemann's test.

The uses of lead are very numerous; persons who



who work much among lead, are subject to a complaint called *colica pictonum*, which may be remedied by sulphuret of potash. Lead is seldom found native, but generally mineralized by sulphur and arsenic. It is sometimes, though seldom, found combined with phosphoric acid.

Iron is the hardest and most elastic of all the metals, and excepting platina, the most difficult to be fused. Next to gold, it has the greatest tenacity of parts. It is about seven times heavier than water. This metal is more useful than any other; it has a very strong attraction for oxygen, which converts its surface into an oxyd, or rust. Iron has the peculiar property of welding in a white heat.

If iron be deprived of its oxygen as much as possible by placing it in contact with red hot charcoal, it becomes much more hard and pure, and is called steel.

Sulphuric acid diluted dissolves iron, and during the solution a great quantity of hydrogen gas flies off. The sulphat of iron thus formed is of a green colour; but is never made for use by art, being extracted from pyrites, or sulphuret of iron.

Nitric

Nitric acid acts very eagerly on iron, and is decomposed, and the iron is thrown down in the form of a red oxyd.

The muriatic acid dissolves iron, and forms a salt, which may be procured in crystals.

Iron is very seldom found pure in nature, but generally combined with some other substance; most commonly with oxygen. It is often combined with sulphur, forming pyrites, the figure of which is sometimes very beautiful. It is sometimes combined with carbon, and then is called plumbago, or black lead.

Iron is never found in veins, like the other metals, but stratified like the earths: and there are strong reasons for suspecting that the greatest part, if not all the iron on this globe, has been of animal or vegetable origin.

## LECTURE XXIV.

**COPPER** is of a dull red colour, and a fine granulated texture when broken ; it possesses considerable ductibility, and may be drawn into fine wire, or beaten into thin leaves ; it is rather more than eight times heavier than water.

Almost all the acids dissolve this metal, but what is remarkable, they dissolve more of it by standing in the cold, than by boiling.

Sulphuric acid, when concentrated and hot, dissolves copper, forming sulphat of copper, or blue vitriol, which may be procured in beautiful blue crystals. One hundred parts of this salt contain thirty of acid, forty-three of water, and twenty-seven of copper.

The



The nitric acid attacks copper very rapidly, and is decomposed. The nitrat of copper is a green diliquescent salt, which has the curious property of exploding when moistened and rolled up in tin foil, as has been before noticed. The muriatic acid when concentrated, dissolves copper, but the muriat of copper is very little known.

The vegetable acids dissolve copper very easily, on which account the use of this metal for culinary purposes is very improper. The solution of copper in the acetous acid, forms acetite of copper, which may be procured in crystals of a beautiful green colour, and which is commonly called verdigris.

Copper readily unites with melted tin, at a temperature much lower than what is necessary to melt the copper; by which means copper vessels are easily covered with a coating of tin.

A mixture of copper and tin forms bronze; two parts of copper and one of zinc form brass, and with different proportions, prince's metal. Copper is sometimes found native, but generally combined with sulphur and oxygen, in ores of a red, green, or blue colour.

Silver

Silver is white, very ductile, and about eleven times heavier than water. If silver, finely divided, be immersed in concentrated and boiling sulphuric acid, the acid is decomposed, and a large quantity of sulphurous gas flies off; and the silver is reduced to a white oxyd.

The nitric acid dissolves silver very rapidly, and when fully saturated, this solution deposits crystals of nitrat of silver. The nitrat of silver is an excellent test for discovering the presence of the muriatic acid.

A fulminating property may be imparted to the oxyd of silver, precipitated from this solution, which is much more extraordinary and terrible than any other substance with which we are acquainted. The silver is precipitated from the solution by lime-water, and afterwards washed with ammoniac.

Gold is the most perfect and indestructible of metals; it appears yellow by reflected light, but green by transmitted light. It is so tenacious, and at the same time ductile, that a grain of it may be beaten out so as to cover fifty-six square inches, but when it is used to cover silver wire, it is spread over a surface 12 times as great. Pure gold is nine-

teen

teen times heavier than water; it melts in a low degree of white heat; it readily unites with the other metals, and particularly with mercury; and on this depends the practice of gilding metals.

Neither the sulphuric, muriatic, or nitric acids, have any effect on Gold, but the nitro-muriatic acid dissolves it very easily; and if it be precipitated from the solution by means of ammoniac, the precipitate explodes when heated, with very great violence.

Gold is generally found pure, mixed with earth, or diffused in fine grains through stones.

Platina is generally found in the gold mines in small particles, and it is the heaviest body with which we are acquainted, being at least twenty two times heavier than water. It is harder than gold or silver, and has the property of welding with iron.

This metal is insoluble in any of the acids, excepting the nitro muriatic and oxygenated muriatic acids; it unites with the other metals, and with copper forms a compound, susceptible of a fine polish, and not liable to tarnish.

From



From the earliest ages of chemistry, it has been thought possible to convert metals into each other; and this transmutation, though hitherto undiscovered by the alchemists, does not appear absolutely impossible: modern chemistry having shown the analogy between metallic oxyds and acids, may perhaps in time lead to the power of transmuting their bases.

Dr. Darwin's theory of the formation of the earth, is very bold and ingenious; he supposes the sun to consist of similar materials to what compose the interior and primary matter of this globe; that during a solar volcano, the earth, along with the other planets; might be projected from the sun; that the rotation of the earth might be occasioned by its adhesion to one side of the cavity from which it was projected; and that from its rotation, as it was then in a liquid state, it would acquire its spheroidal form.—The heaviest substances, viz. the metals, would fall towards the center, and over these would be deposited the earths which compose granite and basaltic rocks; as it cooled, these earths would form a nucleus; and the attending and surrounding vapours, being condensed, would form the ocean, which surrounds the whole globe.

On

On the nucleus of granite covered by the ocean, would be formed calcareous beds of limestone, marble, and chalk, from the exuviz of marine animals; these would become stratified, from their having been formed at very different or distant periods of time. The whole terraqueous globe was probably then rent by central fires; islands and continents would be raised, consisting of granite or lava in some parts, and limestone in others; in consequence of this, great vallies would be sunk, into which the ocean would retire.

On some parts of these islands and continents of granite and limestone, would be gradually produced extensive morasses, from the recrements of vegetables and land animals; and from these would be produced, clay, coal, sulphur, and iron, with the bases of a variety of acids, all of which would be stratified.

In the elevation of the mountains by subterraneous fires, very numerous and deep fissures would necessarily be produced. Into these fissures, many of the metals would be raised, either from their being forced into them in a liquid state, or which is more probable, from their particles being evaporated, condensed, crytallized, and mineralized, in those

those cavities; hence we should expect to find the most volatile metals in the greatest quantities, and *vice versa*, which is consonant to experience.

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## LECTURE XXV.

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THE chemical substances which have been hitherto examined, have no life or peculiar organization, excepting what results from the attraction of their particles. We now proceed to the chemical consideration of those substances, which possess such an organization and irritability, as enable them to fulfil the two great ends destined by nature ;—the continuation of their own existence, and the reproduction of their species.

Though it may at first sight appear very easy to distinguish the three kingdoms of nature from each other ; yet there is such a gradation, such an imperceptible transition of one kingdom into another, that it is difficult to give a characteristic definition of one which embraces all the individuals of it, and at the same time excludes all those of the  
other

other kingdoms. Indeed, on inquiry we shall find, that there is no natural distinction of this kind; and that there is not a function common to vegetables and minerals, which some of the animal tribe do not enjoy, and *vice versa*.

The substances constituting the texture of vegetables differ from mineral bodies, in being of a more complex order of composition; and though vegetables are extremely susceptible of decomposition by analysis, not one can be synthetically produced.

Though the analysis of vegetables shews that they are composed of four or five simple substances, viz. caloric, light, water, air, and carbon, yet nothing but the texture and organs of living vegetables, can from these substances form the matters from which they are extracted.

Though vegetable bodies are composed of these few simple principles, yet we find a great variety of substances produced by their combination; these may be reduced to a certain number of principal heads, which, with Fourcroy, we shall call the immediate materials of plants, because they are obtained from them by simple processes, almost

almost wholly mechanical; and by a kind of direct analysis, which does not alter the nature of the products.

Among these immediate materials of vegetable bodies, are the following substances, either fluid or solid. Extractive matter; mucus, or mucilage; sugar; essential salts; fixed oil; volatile oil; aroma; camphor, resin; balsam; gum-resin; fecula; gluten; colouring matter; elastic gum; and woody fibre. Of these immediate materials, which are formed of some or all of the simple substances before mentioned, all known vegetables are composed. The properties of each of these materials are particularly pointed out in the lecture.

Since these immediate materials are all composed of, and capable of being separated by analysis, chiefly into carbonic and water; it may be proper to inquire how vegetables procure the principles which form these materials.

Water is evidently the source whence vegetables derive the hydrogen; this fluid is decomposed in their glands, assisted by solar light, and becomes fixed in them in the state of oil, extract, mucilage, &c. The greatest part of the vegetable however consists of carbon, which they procure from the decomposition



decomposition of the carbonic acid floating in the atmosphere, or dissolved in the water, which is absorbed by them; when these vegetables decay, their mould affords carbon to future vegetables, which nourishes them luxuriantly. This mould, or carbon, is however gradually exhausted by vegetation when the crop is carried off, and then the farmer is obliged to supply fresh quantities of carbon, which is generally done in the form of dung; the rain water which falls on the ground thus manured, becomes saturated with carbon, and then contains all the principles of vegetation.

These differences seem to depend on animal bodies being possessed of one substance in much greater quantity than vegetables, viz. azote. Besides these circumstances, in which animal substances differ from vegetables, the former generally contain a quantity of phosphoric acid and calca- reous earth.

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**ANIMAL** substances differ from vegetable, principally in the following circumstances. First, they afford a considerable portion of ammoniac, and very foetid products by the action of fire. Second, they putrefy more easily and speedily, giving out a much worse smell. Third, they yield when acted on by the nitric acid, a much greater quantity of azotic gas, and lastly, they contribute singularly to the formation of nitric acid.

These differences seem to depend on animal bodies being possessed of one substance in much greater abundance than vegetables, viz. azote. Besides these circumstances, in which animal substances differ from vegetable, the former generally contain a quantity of phosphoric acid and calca- reous earth.

Azote

Azote, which is so abundant in animal substances, is undoubtedly the cause of their concrescibility and plasticity. If we should deprive animal substances of their azote, they would be converted into substances resembling vegetables, and if we could introduce azote into vegetable substances, we should animalize them.

All matters which form the bodies of animals, and which may be extracted from them without altering their nature, may be considered as so many immediate principles, as was done with respect to vegetables.

The principal animal fluids are, First, the blood, which consists of three immediate materials, or principles, the serum, the crassamentum, or coagulable part, and the colouring part, or red globules, as they are called. Second, milk, which is the least animalized of all the fluids, and consists likewise of three immediate materials, serum, or whey, butter, and cheese. Third, the bile, which is a saponaceous fluid, consisting chiefly of an animal oil, combined with soda. Fat is nothing but animal oil in a coagulated state.

The substances which compose the solid parts of animals



animals may likewise be divided into three immediate materials, or principal genera; First, Albumen. Second, Gelatin. Third, Fibrin, or Fibrous matter. These three substances in a state of concretion and combination, form all the solids of animals, and are separable from each other by an easy analysis. These different immediate principles are particularly examined in the lecture.

By whatever means we deprive animal substances of their azote, we reduce them to substances resembling vegetables; the muscular fibre excluded from the contact of the air, but particularly if in contact with water, parts with its azote, and is converted into a substance resembling spermaceti, which in its analysis, agrees with the common expressed oils of vegetables.

When vegetables and animals are deprived of life, movements are excited in them which destroy their texture, and alter their composition. These movements constitute the different kinds of fermentation.

When the saccharine principle is predominant in vegetables, the product of fermentation is a spirituous, or vinous liquor; when mucilage is predominant,

dominant, the product is an acid, and if the gluten should prove most abundant, the fermentation will be of the putrefactive kind. Hence it is evident that vegetable substances may successively experience all the different kinds of fermentation.

When vegetable substances, particularly saccharine matters, are mixed in proper quantity with water, and exposed to a gentle heat, the water becomes decomposed; its oxygen combines with the carbon of the vegetable, forming carbonic acid, which is disengaged in large quantity during fermentation; at the same time, the hydrogen of the water, uniting with the mucilage, forms alcohol, which being mixed with water, and part of the carbon of the saccharine matter, together with extractive and colouring matter, is called wine. The alcohol may be separated from these matters by distillation with a gentle heat. Pure alcohol appears to be hydrogen in a liquid state, combined with a small quantity of carbon, which most probably causes its fluidity; for we find that the more we deprive it of its carbon, the nearer it approaches to the state of hydrogen gas. Ether seems to be hydrogen, combined with much less carbon. It is convertible into gas with a gentle heat, which very much resembles hydrogen gas in its properties.

The

The acid fermentation is the next natural movement, which contributes to reduce vegetable compounds to more simple states of composition. After vegetables have passed through this state, their decomposition continuing under favourable circumstances, leads to the decomposition of the last principle, the gluten, which terminates in volatilizing most of their principles in the form of gas; after this, nothing remains but a brown or black residuum, called mould, composed of carbon, some salts, a little oil, and extractive matter.

When animal substances, deprived of life, are exposed to the air, their component parts soon become altered by more simple attractions between their principles, which have a tendency to unite two and two together. In the union of hydrogen and azote, we perceive the formation of ammoniac, the combination of carbon with oxygen, explains the evolution of carbonic acid, Nitric acid arises from the union of oxygen and azote. A quantity of hydrogen is extricated in the form of gas, carrying off with it sulphur and phosphorus, which causes the disagreeable smell that attends animal putrefaction; nothing now remains but a portion of carbon, mixed with phosphat of soda and phosphat of lime.

Hence



Hence we see, that by the processes of fermentation and putrefaction, complex bodies are converted into substances less compound; and that nature restores, in the new combinations that are formed, the principles she had borrowed from the atmosphere for the formation of animals and vegetables; and thus she accomplishes the perpetual circle of compositions and decompositions, which demonstrates her fecundity, while it announces equal grandeur and simplicity in her operations.

## LECTURE

Hence we see, that by the process of ferment-  
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 demonstrates her fecundity, while it announces  
 equal grandeur and liberality in her operations.

**FROM** the analysis of vegetables substances it  
 appears, that they are composed chiefly of three  
 principles, carbon, hydrogen, and oxygen; the  
 whole of the woody fibre consists of carbon, the  
 other parts of the vegetable consist of modifications  
 of these three principles, so that carbon is the prin-  
 ciple which is contained by vegetables in the  
 greatest quantity.

Since vegetables as well as animals will be dis-  
 eased, if they receive either too little or too much  
 nourishment, it is evident that the great business of  
 agriculture must be,

1. To supply plants with proper nourishment.
2. To supply that nourishment in proper quan-  
 tity. The

The first is accomplished by the application of manures; the latter depends upon the simple elementary earths in which plants grow, being of such consistency or in such proportion, as to transmit nourishment to plants in proper quantity.

From the decomposition of water, plants gain their hydrogen, and in the case where they are not supplied with carbon directly in the form of manure, but only absorb water impregnated with carbonic acid, it is evident that they must decompose that acid, and apply the carbon to the formation of the woody fibre. As much of the oxygen of the water and carbonic acid as is necessary to form the vegetable juices is retained, while the remainder is perspired by the plant in the form of gas, which purifies the atmosphere.

There is no doubt then that plants do obtain carbon by the decomposition of the carbonic acid which is dissolved in water; yet this fluid seldom contains a sufficient quantity of that gas to make vegetables grow vigorously and luxuriantly. In grounds however, where vegetables are not carried off, but suffered to decay, their relicks afford a sufficient quantity of carbon for the nourishment of the future vegetable; but if the crops be taken off,

this



this carbon will in a few years be exhausted; and if the same crop is to be continued, a fresh quantity of carbon must be supplied by the farmer. Carbon not only forms the residuum of all vegetables which have decayed, or undergone a smothered combustion, but also of all putrid vegetable and animal bodies; hence it is found in all vegetable and animal bodies that have undergone putrefaction, and is the true basis of their nutritive powers, as manures. Carbon however cannot produce its beneficial effects unless it be soluble in water, for in no other state can it be absorbed by the plant. The process of both animal and vegetable putrefaction is accompanied by that of oxygenation, forming carbonic acid, which is eagerly dissolved in water and absorbed by plants. But all vegetables after death, even before putrefaction, unite with a quantity of oxygen, though not sufficient to convert them into carbonic acid; and in this state they form excellent manures, for though they are then in a great measure insoluble, yet when spread upon the surface of the ground, they are by the action of air and water, converted into carbonic acid.

To this process of partial oxygenation, the continuance of vegetable matter on the surface of the earth is to be chiefly ascribed.

Having

101 Having shown what is the proper food of plants, and that if they be supplied with water and carbon, and exposed to the influence of light, which assists in the decomposition of the water and carbonic acid, they will grow and live, I shall next take a short view of the nature of soils, or the mixture of the simple earths most proper for transmitting these nutritive principles to vegetables.

The earths in which vegetables grow, consist chiefly of a mixture of calcareous, silicious, and argillaceous earth, which do not afford any nourishment to the vegetable, but when mixed in proper proportions, they retain and transmit the nourishment as it is wanted; without such a precaution, plants would have been exposed to the dreadful alternative of being either parched up by heat, or deluged with water. The same soil, or mixture of simple earths, will not however suit every plant, but ought to be varied according as a plant has need of a more or less quantity of water, and according as it is necessary for its roots to extend to a greater or less distance.

A soil proper for vegetation ought to possess the following properties. First, it should be of such a consistence as to afford a firm mechanical support

to

to the plant. Second, it should be such as to suffer the roots of the plant to extend with ease to a proper distance. Third, it should be enabled to retain a sufficient degree of humidity to supply the demands of the plant.

In order to obtain these properties, it is necessary that the elementary earths should be mixed together in proper proportion, for none of them is alone possessed of the qualities required. Hence likewise we see the necessity of being acquainted with the chemical properties of a soil, before we can ameliorate it by tillage. The method of analyzing different soils is particularly pointed out in the lecture. In ascertaining the proportions of the simple earths, in order to form the most fertile soil, regard must however be had to the quantity of rain which falls; for it is evident, that where the fall of rain is great, the soil ought to be such as not to be very retentive of moisture, and the contrary. Hence we see the necessity of meteorological observations to the farmer.

M. Tillet has shown, that the most fertile soil for wheat, in flat countries, where a moderate quantity of rain falls, is composed of  $\frac{1}{3}$  of argil,  $\frac{1}{3}$  of sand, and  $\frac{1}{3}$  of calcareous earth.

As



As a component part of soils, iron must not pass unnoticed, as it seems to promote the solution of carbon. The iron exists in the state of an oxyd, the oxygen of which combining with the carbon of the manure, forms carbonic acid. When the carbon is exhausted, the iron again oxydates, and is then in a condition to act as before, on fresh carbon which is spread on the ground. Paring and burning ought to be practised with judgment, for there are only some soils which will bear it, as nothing exhausts the soil so quickly as this operation. Some lands may however be benefited by it, such as peaty grounds, or soils covered with a sward of unprofitable herbage, and containing a superabundance of vegetable matter. The combustion should be conducted in as slow and smothered a manner as possible, that the carbon may not be consumed.

In some countries gypsum, or sulphat of lime, is employed as a manure, but is not much used in this island; it seems to act more as a septic, in promoting the destruction of vegetable matters, and consequently the solubility of carbon, than as affording any nourishment to vegetables; and hence it is not ploughed in like other manures, but only strewed upon the land, and generally in the month of February, to convert the old grass quickly into carbon, that it may nourish the young. It

It has lately been found that steeping seeds in the oxygenated muriatic acid, had a particularly beneficial effect in producing vigorous and early plants; and that the same liquor poured upon the ground has likewise a beneficial effect. Does the oxygen here promote the solution of the carbon? This subject deserves farther investigation.

## LECTURE

## LECTURE XXVIII.

If vegetable bodies of different colours be placed into the oxygenated muriatic acid, they disappear more or less speedily and perfectly: when the substance is more or less soluble in the acid, the colouring parts disappear more easily, and leave only those which resist effectually, with the power of this agent, but have nevertheless suffered considerable alterations. The yellow colouring matters usually resist the most strongly, but at length they all dis-

AN account is first given of the old method of bleaching cottons and linens, and the common modes of bleaching woollens and silks, which are well known. The greatest improvement that has been made in bleaching is that by M. Berthollet, by means of the oxygenated muriatic acid.

Scheele was the first who introduced this acid to our acquaintance, and observed the effects which it produces on the colouring parts of vegetables; but it was Berthollet who first thought of applying it in an extensive way to the purposes of bleaching.

Scheele thought that the oxygenated muriatic acid gas, procured by distilling muriatic acid from manganese, possessed but little solubility in water; but Berthollet found, that it may easily be dissolved in large quantity in that fluid.

If



If vegetable bodies of different colours be plunged into the oxygenated muriatic acid, they disappear more or less speedily and perfectly; when the substance possesses a mixture of different colouring parts, some disappear more easily, and leave only those which most effectually resist the power of this agent, but have nevertheless suffered considerable alteration. The yellow colouring matters usually resist the most strongly, but at length they all disappear, and when the oxygenated muriatic acid has exerted its whole action, it is found reduced to the state of ordinary muriatic acid. Hence it appears, that the colouring matters have deprived it of its oxygen, and have by this combination acquired new properties, at the same time they have lost that of producing colours. From this it was not unnatural to conclude that this liquor might produce the same effect upon those substances which colour cotton and linen, and which it is the business of the art of bleaching to destroy.

M. Berthollet first tried the effects of this acid, without any previous preparation of the substances to be bleached, but he soon found, that though he succeeded in bleaching his cloth without injuring it, yet it became yellow by keeping; his reflections were therefore directed to the circumstances of the

the usual process of bleaching, which he endeavoured to imitate.

The exposure of cloth to air in bleach grounds, will not bleach it, for it only combines the colouring matters with oxygen, which renders them soluble in alkaline lixivium; the oxygenated muriatic acid, by imparting its oxygen, produces the same effect in a few hours, which is produced by exposure to the air for a very long time; he therefore tried alternately the immersion in oxygenated muriatic acid and alkaline lixivium, and succeeded perfectly in producing a permanent white. This mode of bleaching has since come into considerable use, and is undoubtedly a very great improvement. Cloths which required a long time to bleach them, may be now completely finished in a few days; the new mode of bleaching may be carried on in winter nearly as well as in summer, and those fertile meadows, which during the finest and most productive part of the year are covered with cloth, may be subjected to agriculture.

The oxygenated muriatic acid was at first procured by distilling the muriatic acid from manganese in Woulfe's apparatus; but as soon as M. Berthollet had reason to hope that the process might

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be

be executed in the large way, he endeavoured to diminish the price of the liquor, by decomposing muriat of soda, or common salt, in the same operation which served to form the liquor; which he did, by mixing together in the retort, common salt, and the black oxyd of manganese, and pouring upon the mixture diluted sulphuric acid, which expels the muriatic acid from the soda in the form of gas, which gas attracting oxygen from the manganese, comes over, and is dissolved by the water in the receiver. The proportions directed by Berthollet are six parts of powdered oxyd of manganese, sixteen of sea salt, and twelve of concentrated sulphuric acid, diluted with an equal quantity of water. In order to judge of the strength of the oxygenated muriatic acid, a solution of indigo in the sulphuric acid may be used. Mr. Watt recommends for the same purpose, a solution of cochineal in water.

The apparatus for procuring the oxygenated muriatic acid, has been much improved by different bleachers and chemists, and is now very convenient. The most approved machines for this purpose are described in the lecture.



## LECTURE XXIX.

**DYING** is the art of tinging cloth, stuff, or other matters, with a permanent colour, which penetrates its substance. It is an art of very great antiquity, and is more or less practised in almost all nations, whether civilized or savage.

The most remarkable general fact in the art of dying, consists in the different degrees of facility with which animal and vegetable substances attract and retain colouring matter; or the degree of facility with which the dyer can tinge them with any intended colour.

The substances to be operated on by the dyer, are animal or vegetable, of which the former are much more easily dyed than the latter, and this seems

seems chiefly to depend on the difference of their constituent parts. The chief chemical difference between animal and vegetable substances, is, that the former contain only a small portion of carbon, which is the most fixed elementary substance, and a large quantity of hydrogen and azote, both of which are very volatile; while vegetables contain a very large portion of carbon, less hydrogen, and in general no azote; and as the azote and hydrogen readily assume an elastic form, of which carbon is incapable; the wool, hair, and silk, in which these substances abound, have less adhesion between their constituent parts, than what exists between those of cotton, linen, &c. and are therefore more strongly disposed than the latter to combine with other substances, when heated and brought into contact with them; and it is probably in consequence of this disposition, that wool, hairs, and silk, manifest stronger affinities or attractions for colouring matters, than cotton and linen; it being well known to dyers, that cotton and linen will neither of them receive any colour by the same preparation, or in the same liquor which dyes wool, or woollen cloth scarlet. Wool and silk are also more readily decomposed, or injured by acids, alkalies, and other chemical agents; which ought therefore to be more sparingly used in the dying of animal, than of vegetable substances.

Wool

Wool is naturally so much disposed to combine with colouring matter, that it requires but little preparation for the immediate process of dying; but silk must first be freed from a kind of varnish with which it is covered, by boiling either in pure water, or a very weak solution of alkali; it must then be bleached, by exposure to the fumes of sulphur. Cotton and linen are cleared of their tinging matter by boiling them in a solution of fixed alkali, they are then to be bleached, either by exposure to the air and solar light on bleach grounds, or by immersion in the oxygenated muriatic acid. The stuff being thus bleached, will not only imbibe the colouring matter of the dye more readily; but being rendered whiter, is more capable of reflecting the light that falls upon it through the colouring matter, and thus exhibits more brilliant tints.

In general the particles of cotton and linen have little attraction for the colouring matters, and therefore could not be dyed but by means of intermediate affinity. The substance to be dyed must first be impregnated with a substance which has an attraction both for it and for the colouring matter, and then when the latter is applied, it will adhere to it firmly. These intermediate or connecting substances



stances have been called mordants, or bases; the most remarkable are argil, and some metallic oxyds.

If the base be universally applied over the piece of goods, and this be afterwards immersed in the bath, it will receive a permanent tinge over its whole surface; but if it be applied only in parts, the dye will strike those parts only. The former process constitutes the art of dying properly so called; and the latter the art of printing, staining, or painting.

In the art of printing, the mordant, or base, (which generally consists of argil, or iron) is mixed with gum, and applied by means of blocks, or wooden engravings in relief. The piece is then immersed in a solution of cow's dung, which among other effects, seems to act by covering those parts to which the base has not been applied, with a mucilaginous matter, which renders them less capable of receiving the dye. The colours are then brought out in a bath, filled with suitable compositions; very often a decoction of madder is used, and when this is the case, if an argillaceous basis has been applied, the whole will come out of a red colour. With the piece in this state, the printer has only to avail himself of the difference between a fixed and fugitive

fugitive colour. He therefore boils the piece in bran, or brewer's grains, which take up part of the colour, and then the common mode of bleaching takes away the remainder from all parts excepting those to which the base has been applied, which will continue of a permanent red. If the base be iron, then the part printed will be black, but if it be a mixture of argil and iron, the permanent colour will be purple; and it is evident, that by printing the same piece with these bases, both separate and mixed, the three colours will be produced by the bath.

In order to form the argilacious base, sulphat of alumin is mixed with acetite of lead. In this case a double decomposition takes place. The sulphuric acid uniting with the lead, forms sulphat of lead, which is precipitated, and thrown away, and the acetite of alumin being formed of a proper consistence by means of starch, or gum, is applied by the blocks; the piece is then exposed to a sufficient heat to drive off the acetous acid.

The iron basis is formed by acetite of iron; and the acetous acid is likewise driven off by heat.

The

The materials for dying are very numerous ; some produce durable colours, which cannot be discharged either by exposure to the air, or by washing with soap, others, though they will stand the action of soap, cannot resist that of the air. The most permanent dyes we have, are cochineal and gum lac for fine reds and scarlets ; indigo and woad for blue ; and these last when mixed with different proportions of the others, for purples and violets ; weld, and some vegetables, for yellows ; and madder for coarse reds, purples, and blacks.—The fading colours are much more numerous ; in this class are included log-wood, brazil-wood, peach-wood, red-wood, fustic, archil, &c.

Indigo must first be deoxydated by means of orpiment, or sugar, it then becomes soluble in the bath ; but the substance dyed by it comes out of a green colour, which soon changes to a blue by the absorption of oxygen from the atmosphere. Sulphat of indigo dyes the saxon blue, and the quercitron bark is now much used in dying and printing.

There is no art which depends so much on chemistry as dying, yet its principles are by no means well established ; neither are the facts connected



nected by a satisfactory theory; but as chemists are now become dyers, and dyers chemists, we may hope that this art will soon assume a more scientific form.

LECTURE XXX.

In the investigation and analysis of mineral waters, the soluble quantities are first to be carefully observed; these are by no means circumstances of small importance; for they will serve to indicate the properties we are to use, and have much to do. The principal properties, such as specific gravity, temperature, &c. ought then to be well ascertained. When these circumstances have been observed, we must examine the water by chemical tests, or specific

### LECTURE

In order to ascertain whether the water contains any iron, a little solution of gallic or prussic acid must be dropped into some of it, and if a purple or blue colour be produced, we may be assured that it does contain iron. The next object is to ascertain whether this metal be suspended by the carbonic acid.

## LECTURE XXX.

IN the investigation and analysis of mineral waters, the sensible qualities are first to be carefully observed; these are by no means circumstances of indifference; for they will serve to indicate the processes we are to use, and save much trouble. The physical properties, such as specific gravity, temperature, &c. ought then to be well ascertained. When these circumstances have been observed, we must examine the water by chemical tests, or precipitants.

In order to ascertain whether the water contains any iron, a little tincture of galls, or prussiat of potash must be dropped into some of it, and if a purple or blue colour be produced, we may be assured that it does contain iron. The next object is to ascertain whether this metal be suspended by the carbonic acid,

acid, or by some of the more fixed acids; which may be done by boiling it for a short time, and then examining it by the same tests. If it still changes colour, the iron is suspended by a fixed acid.

The presence of carbonic acid may be ascertained by tincture of turnsole. This test likewise discovers the presence of any other acid, and it may be determined whether it be the carbonic or any other acid, by boiling the water.

Paper dipped in an infusion of red cabbage, is a delicate test of the presence of both acids and alkalies, the former of which turn it red, and the latter green. Paper on which characters have been written with a solution of acetite of lead, is a test of the presence of sulphurated hydrogen gas. The presence of the sulphuric acid is ascertained by muriat of barytes; that of lime by the oxalic acid; and of alkalies by the aqueous infusion of brazil wood.

By means of these precipitants, varied in a proper manner, we shall be enabled to form a judgment of the nature of the contents of a mineral water, which will greatly facilitate the analysis, and prevent many unnecessary trials.

The



The next thing to be done, is to ascertain the nature and quantities of the aeriform, or elastic fluids which these waters contain. These gases may be best procured from the waters by means of a simple machine, described in an essay which I published on the Crescent water at Harrogate. When the quantity of gas procured has been accurately measured, the different kinds must be separated from each other.

When carbonic acid and azotic gas are mixed together, if they be agitated over water, that fluid will absorb the former, but not the latter, so that the quantities of each may be ascertained. When the water contains carbonic acid, sulphurated, hydrogen, and azotic gas, the bulk of the whole must first be ascertained. Some fresh water is then to be put into the machine, and a quantity of quicklime added to it, which will absorb the carbonic acid gas, and its quantity may be ascertained, by subtracting the remainder procured by the machine, from the whole quantity at first procured. What remains is a mixture of sulphurated hydrogen and azotic gas, the former of which may be separated from the latter by agitation over water, and their respective quantities ascertained. In the analysis of sulphureous waters, the sulphurated hydrogen gas ought

ought always to be separated before we evaporate them, otherwise, during the evaporation, part of the sulphur deposited by this gas, on its union with the oxygen of the atmosphere, is converted into sulphuric acid, which greatly changes the nature of the salts contained in the water.

The next step in the analysis, is to evaporate a considerable quantity of the water in order to ascertain the solid contents. The water should first be made to boil gently, that the gases may be expelled, the matters which they held in solution will then be precipitated, and may be collected by filtration; the remainder of the water must then be evaporated slowly to dryness, and the residuum collected and weighed.

This residuum is then to be put into a phial, and alkohol poured over it to the height of an inch; it must be well shaken, and after standing a few hours, must be filtered. The alkohol dissolves the diliquescent salts, such as muriat of lime and muriat of magnesia, but will not touch such as are not diliquescent. To the residuum, not soluble in the alkohol, is to be added eight times its weight of cold distilled water; the mixture must be shaken, and

and after standing a few hours, must be filtered. The residuum must next be boiled for half an hour, in 500 times its weight of distilled water, and afterwards filtered. What remains is now insoluble either in alcohol or water, and generally consists of argillaceous or silicious earths, which may be easily separated from each other, and their quantities ascertained. The solution made by boiling in distilled water, contains chiefly sulphat of lime, the quantity of which may easily be ascertained by evaporation.

We must next examine the spirituous solution, which, as was before observed, contains in general muriat of lime, and muriat of magnesia; this solution must be evaporated to dryness, and weighed. Diluted sulphuric acid is then to be poured on the salt, which will not only show the presence of the muriatic acid, by the white fumes disengaged, but will unite with the lime and magnesia, forming sulphats with these earths, the latter of which is soluble, but the former possesses very little solubility; in consequence of which they can be easily separated, and the quantities of muriat of lime and muriat of magnesia easily ascertained, when the quantities of sulphat of lime and magnesia are known.

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The solution made in cold distilled water is next to be examined, and crystallization attempted, which will enable us, with the assistance of proper tests, to ascertain both the nature and quantity of each salt which it contains.

When a water has been thus analyzed, we must next confirm our analytical proof by synthesis, and if we can produce a water perfectly similar to the water we have examined, we may rest satisfied with our analysis.

When a water contains lime, dissolved either by the sulphuric, carbonic, or any other acid in considerable quantity, it is much less fit for obtaining extracts from solid substances, for brewing, distilling, preparing decoctions of coffee, or infusions of tea, and many other uses than pure water, and is usually denominated hard. Such water is likewise more or less unfit for washing linen, partly because it will not easily dissolve the greasy matters, but chiefly because it decomposes soap. For these reasons hard waters are totally useless in bleaching, and are unfit for boiling peas, beans, and other pulse.

The lime in hard waters is generally suspended by the sulphuric and carbonic acids. Oxalic acid  
will

will show the presence of lime; muriat of barytes that of sulphuric acid, and lime water, or tincture of turnsole, that of the carbonic acid.

If carbonat of lime renders the water hard, it may be purified by boiling, which drives off the carbonic acid, and the carbonat of lime suspended by it will be precipitated; but when it is caused by sulphat of lime, a fixed alkali must be added, which precipitates the earthy base; for this purpose a solution of common potash may be poured into a given quantity of the water as long as it occasions any turbidness, and after the precipitate has subsided, we may still try whether the alkali will precipitate any more lime: in this way we may determine the quantity of alkaline salt which a given quantity of water requires for its correction, and when once this is done, we can put the proper quantity of the salt into the water, let it stand a few hours, then decant the liquor from the sediment, and it will be fit for washing, or any common purposes. Putrid waters are best purified by agitating them in contact with powdered charcoal, which may be easily done at sea, and will render them perfectly sweet; if the insides of the water casks be previously charred, they will preserve the water sweet for a long time.

THE END.

